PB-243 151

NORTHERN GREAT PLAINS RESOURCE PROGRAM, MINERAL RESOURCES WORK GROUP REPORT

Northern Great Plains Resource Program

Prepared for:

Department of Agriculture
Department of the Interior
Environmental Protection Agency

February 1974

DISTRIBUTED BY:

NTIS
National Technical Information Service
U. S. DEPARTMENT OF COMMERCE

BIBLIOGRAPHIC DATA SHEET

1. Report No. NGPRP/CD-74/300

2.

3. Recipient's Accession No.

4. Title and Subtitle
Northern Great Plains Resources Program
Mineral Resources Work Group Report

5. Report Date February 1974

6.

7. Author(s) Mineral Resources Work Group

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Northern Great Plains Resources Program
Denver Federal Center
Bldg. 67, Room 820B
Denver, CO 80225

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address
Department of Agriculture, Department of Interior,
Environmental Protection Agency, States of Montana,
Nebraska, North Dakota, South Dakota, Wyoming

13. Type of Report & Period Covered Discussion Draft

14.

15. Supplementary Notes

16. Abstracts

Analyzes the energy resources and their present status of development in a 63 county area of North Dakota, Montana, Wyoming, and South Dakota. Analyses are presented on: 1) The coal resources; 2) Reserves; 3) Coal ownership; 4) Legislative procedures for leasing federal coal; 5) Current coal mining technology; 6) Potential methods of recovery; 7) Evaluations of surface versus underground mining; and 8) Constraints to developing coal and non-coal mineral resources. In addition hypothetical synthetic natural gas conversion and steam electric power generation and export mine facilities are sited for three alternative levels of coal production. Sitings and alternative production levels are used as a means of assessing impacts by this and other work groups.

17. Key Words and Document Analysis. 17a. Descriptors

Northern Great Plains
Montana
North Dakota
Wyoming
South Dakota
Coal
Energy
Siting
Leasing procedures
Resources

Ownership
Development
Strip mining
Underground mining
Location
Amounts
Availability
Impacts

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group

PRICES SUBJECT TO CHANGE

18. Availability Statement
No restriction on distribution

19. Security Class (This Report) UNCLASSIFIED

20. Security Class (This Page) UNCLASSIFIED

21. No. of Pages 225

22. Price $7.25-2.25

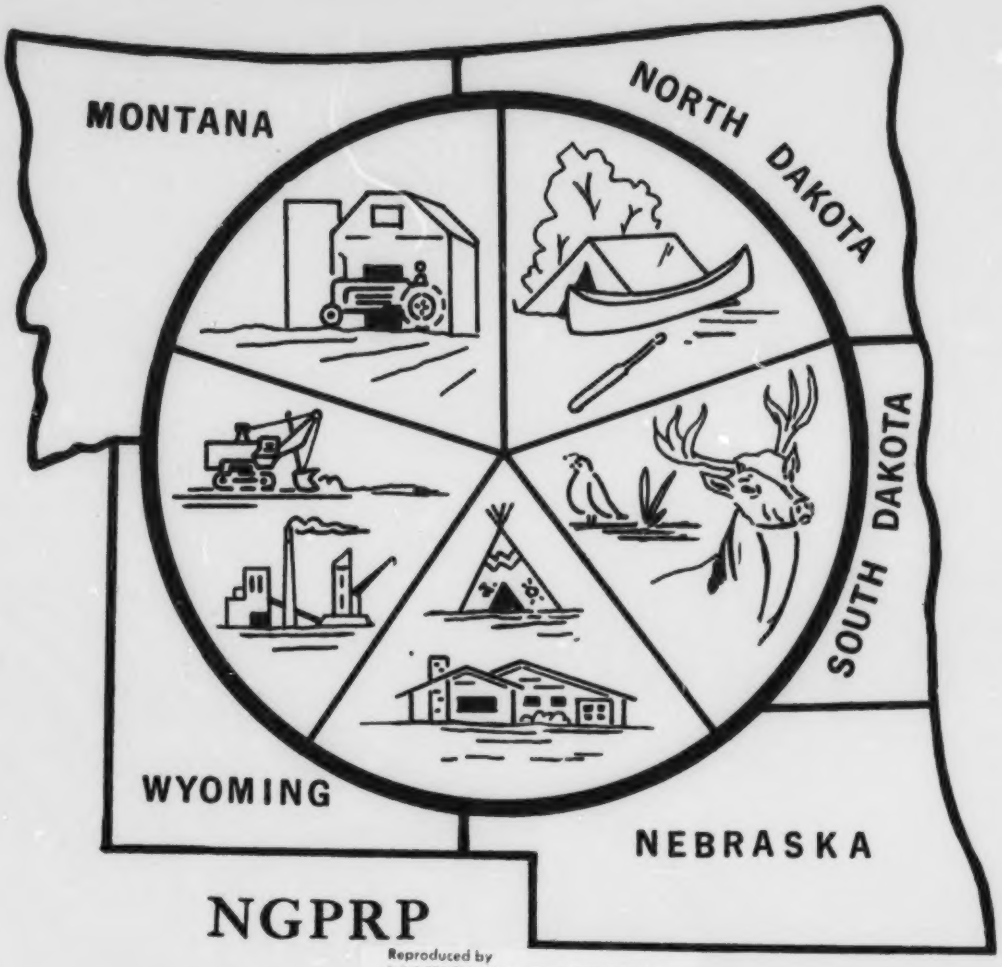
FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

198014

PB 243 151

NORTHERN GREAT PLAINS RESOURCE PROGRAM

MINERAL RESOURCES WORK GROUP REPORT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DEPARTMENT OF INTERIOR

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NORTHERN GREAT PLAINS RESOURCES PROGRAM

MINERAL RESOURCES WORK GROUP

DISCUSSION DRAFT

FEBRUARY 1974

THIS REPORT WAS PREPARED PURSUANT TO A DIRECTIVE DATED OCTOBER 23, 1973, FROM THE PROGRAM MANAGER, NORTHERN GREAT PLAINS RESOURCES PROGRAM. PUBLICATION OF THE FINDINGS AND RECOMMENDATIONS HEREIN SHOULD NOT BE CONSTRUED AS REPRESENTING EITHER THE APPROVAL OR DISAPPROVAL OF THE SECRETARY OF THE INTERIOR, THE SECRETARY OF AGRICULTURE, THE ADMINISTRATOR OF THE ENVIRONMENTAL PROTECTION AGENCY, OR THE STATES OF MONTANA, NEBRASKA, NORTH DAKOTA, SOUTH DAKOTA, AND WYOMING. THE PURPOSE OF THIS REPORT IS TO PROVIDE INFORMATION AND ASSISTANCE TO THE PROGRAM MANAGEMENT TEAM IN THE PREPARATION OF THE DRAFT INTERIM REPORT ON THE NORTHERN GREAT PLAINS RESOURCES PROGRAM. THE PROGRAM MANAGEMENT TEAM IS RELEASING THIS DRAFT FOR PUBLIC USE WITHOUT CORRECTING INCONSISTENCIES OR REWRITING BECAUSE THE DELAY REQUIRED TO ACCOMPLISH THIS TASK WOULD DELAY THE TIMELY ISSUANCE OF THE REPORTS.

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PREFACE

The lead agency for the Mineral Resources Work Group, Work Group B, in the Northern Great Plains Resource Program was the U.S. Department of the Interior, Bureau of Mines, Intermountain Field Operation Center, Denver, Colorado. Lead agency personnel active in the preparation of the work group manuscript were:

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SUMMARY

1. New mines were projected to meet the demand for coal in the Northern Great Plains under the three development forecasts to the year 2000. Nine new mines were projected under the Base forecast for power generation and export with a yearly capacity in the year 2000 of 32 million tons. Under the Most Probable forecast, 36 new mines were projected for gasification, power generation, and export with a yearly capacity of 266.1 million tons in the year 2000. Under the Extensive Development forecast, 100 new mines were projected for gasification, power generation, and export with a yearly capacity of 895.5 million tons in the year 2000. In addition to these new mines, production from existing mines was projected to supplement the supply of coal to meet projected demands.

2. Coal resources in the Northern Great Plains Region, in beds 5 feet or greater in thickness and less than 1,000 feet below the surface in the measured and indicated categories, as of June 1, 1973, total 231,274 million tons. Reserves minable by surface methods total 68,138 million tons. An additional 10 billion tons have been added to the regional resource base by further exploration since the resource data of the region were tabulated for this manuscript.

3. Coals in the Northern Great Plains are predominately of subbituminous and lignite rank. Analyses were performed for moisture, ash, sulfur, and Btu value of selected coalbeds, as well as analyses for 12 trace elements in 67 coal samples, and are presented in tables in the manuscript.

4. An evaluation of surface versus underground coal mining methods was performed, considering such parameters as the environment, surface and ground water, manpower, resource conservation, and economics. Under current technology and the unique coalbed conditions existing in the Northern Great Plains, it is concluded that surface coal mining has the least detrimental impact upon all aspects considered and will be the primary means of coal extraction for purposes of this study. Nevertheless, additional work is necessary to advance the state-of-the-art of reclamation practices and to develop adequate underground recovery techniques to extract the thick-bedded coal which cannot be recovered by surface mining.

5. Constraints to increased coal production are in two broad categories: legislative restraints and mining equipment personnel constraints.

A current U.S. Senate bill on mined-land reclamation would, by amendment, prohibit the surface mining of Federal coal land where the surface is privately owned. To deny surface-mining access to this coal would remove 5,974 million tons (about 9 percent of the total coal, but over 50 percent of that leased) from the region's minable coal reserve since these reserves cannot be recovered by current underground mining technology practiced in the United States.

Information on the availability of mining equipment, mining personnel, and coal transportation equipment is not sufficient to allow detailed analyses of possible shortages which could affect each of the three development forecasts. However, available data suggest that equipment constraints could hamper mine development for the Most Probable and Extensive Development forecasts.

6. Underground mining systems developed in Europe to recover thick coal beds may be applicable to underground conditions in the Northern Great Plains. However, European mining systems use considerably more timber than is used in this country and the mines are more labor intensive and labor is cheaper. It would take 5 to 10 years to prove the applicability of such a mining system in the United States. However, even if technically feasible, there is no guarantee that such a system would constitute an economically viable operation in terms of economic considerations currently utilized in the United States. However, if the economics of energy conversion change appreciably, what is today viewed as economically unattractive may become economically viable.

7. Development of the coal resources in the region could stimulate production of other mineral commodities, particularly those used in construction. Coal development could also conflict, to an unknown degree, with the region's potential for uranium production.

INTRODUCTION

The Northern Great Plains Region covers approximately 142,000 square miles in the 63-county area in eastern Montana and Wyoming and western North and South Dakota. Much of the area is underlain by coal-bearing strata of the Fort Union and Wasatch formations.

The study area, part of the Louisiana Purchase, became United States territory in 1803. Since the first settlers arrived, a series of land and mineral ownership laws enacted in an attempt to encourage settlement, yet preserve the mineral wealth of the region for the good of the United States, have created a complex disorder of surface and mineral ownership. Data on both surface and mineral ownership have been summarized by the U.S. Bureau of Land Management and are presented on plates B-1 and B-2.

Coal was first discovered in the region by early explorers, but was not developed, to any extent, until the construction of the transcontinental railroads. For many years, western coal was used predominately for locomotive fuel. With the passing of the coal-fired locomotive, coal production in the region dropped to a few million tons per year.

During the 1960's and 1970's, the expanded development of large machinery for surface mining, the demand for low-sulfur boiler feed for steam-electric generating plants, and the development of the unit train concept and associated favorable economics for long distance coal transportation created an enormous demand for the less-costly-to-mine coals in the Northern Great Plains Region.

A period of intensive exploration and leasing by coal companies and individuals, initiated in the 1960's, continued into the 1970's, was suppressed by the Secretary of the Interior's moratorium on coal leasing in the summer of 1972. During the late 1960's and early 1970's, the U.S. Bureau of Mines, U.S. Geological Survey, the Montana Bureau of Mines and Geology, and the Wyoming Geological Survey published reports on the known, near-surface coal deposits of the region. These data were used in conjunction with data supplied by The North American

Coal Corporation to construct a map showing near-surface deposits of coal in the Northern Great Plains. This map is illustrated on plate B-3.

The following sections discuss coal development, resources, legislation, chemistry, current and potential coal mining methods, compare and contrast the effects of surface and underground mining, and discuss constraints to increased coal production. The noncoal mineral resources within the Northern Great Plains are discussed and conclusions and recommendations for areas of additional investigation are listed.

CRITERIA AND METHODOLOGY FOR MINE-SITE SELECTION

Introduction

The projection of mine sites under the Base, Most Probable, and Extensive Development forecasts is not meant to be a definitive statement of actual future coal development in the Northern Great Plains Region. Rather, it is a speculative picture of the development potential, given current technology and practice as a basis for projection. It is presented with the full realization, in the absence of a reliable crystal ball, of the inherent uncertainty of the future, and under the constraints of limited time and resources. However speculative, the projections were necessary to enable a comprehensive evaluation of impacts of coal development to be based upon a consistent set of assumptions.

Projections were made for coal production to satisfy four major market sectors--synthetic natural gas production; steam-electric power generation; out-of-state export; and household, commercial, and industrial demand--from coal mines in Wyoming, Montana, and North Dakota.

South Dakota and Nebraska will most likely import coal to meet their immediate requirements; therefore, no mine sites were projected for these states. Furthermore, no attempt was made to identify the source-mines to supply these two states. The numbering of mine sites is not meant to imply any specific order for development; rather, it was merely selected for convenience in constructing the tables.

Information on coal demand, by state, for the various market sectors was obtained from tables D.1, 6.1, and E.1 of the draft report by the Energy Work Group (G). Information on current and future production from existing mines in the study area was obtained from the table, entitled "NGPRP coal production, actual and projected," from the draft report by the Mineral Resources Work Group (B). Sources of information influencing site selection include various newspaper and magazine articles; Federal, state, and private publications; and conversations with various state people.

The Energy Work Group's projections of coal demand were presented on the basis of state boundaries, not the boundaries of the study area. Therefore, it was necessary to allocate a portion of the demand to coal-producing areas of Wyoming which fall outside the Northern Great Plains Resource Program area. Such allocation was not deemed necessary in Montana or North Dakota. The following table summarizes allocation of demand in Wyoming.

Year	Energy Work Group projections (million tons)	Siting allocations (million tons)	
		NGPRP area	Non-NGPRP area[1]
	(Base Forecast)		
1971	8.1	4.2	3.9
1980	37	29	8
1985	43	33	10
2000	53	39.7	13.3
	(Most Probable Forecast)		
1971	8.1	4.2	3.9
1980	47	35	12
1985	73	60.5	12.5
2000	110	91.9	18.1
	(Extensive Development Forecast)		
1971	8.1	4.2	3.9
1980	47	35	12
1985	153	133.4	19.6
2000	386	360.8	25.2

[1] Because of changes in criteria to reflect actual conditions of coal heating value, these figures are only approximate in relation to projections by the Energy Work Group.

Synthetic Natural Gas Production

There is no provision for synthetic natural gas (SNG) production under the Base forecast. Mine-mouth plants were assumed for the Most Probable and Extensive Development forecasts. Each plant is assumed to have a capacity of 250 million standard cubic feet per day (MMscfd) of SNG, with a plant life of 20 years. Plant life will likely increase to 30 to 35 years for second- and third-generation SNG plants.

The Energy Work Group assumed mine size to supply each SNG plant to be 7.6 million tons per year (MMtpy), using an average of 15 million Btu per ton of coal. In order to relate tonnage requirements to the heating value of the coal at each projected site, the Energy Work Group's tonnage figures were converted back to the number of plants in each state. Then assuming 137.5 X 10^{12} Btu of coal input per year of plant operation, an average figure based upon the coal requirements of those SNG processes for which such information is available, tonnage requirements for each site were calculated using the heating value of the coal at the projected site. This figure shows up in the tabulations.

First priority was given those sites for which feasibility studies or actual construction plans had been announced, particularly if water rights also had been secured. Lease ownership information and coal deposit size were also considered. Coal quality was not taken as a deciding factor for SNG plant siting, as it appears from the literature that appreciable variations in quality can be tolerated in the gasification process.

Proximity of water sources and gas pipelines was not directly considered as a constraint, although indications of the availability of an adequate source of water did influence siting selection. However, the availability considered only that a drainage course lay nearby and did not consider potential water availability in that drainage. Gas transmission lines with direct routes to major markets are scarce and little is known about their capacities and availabilities, particularly if new reserves of natural gas are discovered in the region. It is likely that new pipelines would be required to transport SNG to markets.

Steam-Electric Power Generation

Mine-mouth plants were assumed for steam-electric power generation in Wyoming, Montana, and North Dakota, with plant life taken as being 35 years.

The Energy Work Group assumed 4.15 MMtpy of 15-million-Btu-per-ton coal to fuel a 1,000 megawatt plant. In relating tonnage requirements to the heating value of the coal at each projected site, the Energy Work Group's tonnage figures were first converted to power demand in megawatts for each state. It was then assumed that individual power plants would have capacities of 1,000 to 1,250 megawatts. Then, assuming 65 X 10^{12} Btu per year per 1,000 megawatts, based upon a heat rate of 9,400 Btu per kilowatt-hour and operating efficiency of 80 percent, the heating value of the coal at each projected plant site was used to determine the tonnage requirements reflected in the tabulations.

Mine sites to fuel steam-electric power plants were projected under all three development plans for the target year 2000. Expansion of existing mines was assumed to provide feedstock for power generation in prior target years.

Few announcements of intention-to-build power generation facilities have been made beyond the 1980 to 1985 period, but have been considered where available. Quality and quantity of the coal were also taken into account. Proximity of power transmission lines was not a factor in selecting sites, as this does not appear to have been a major factor in the siting of previous facilities. However, proximity to a potential source of water did influence site selection.

No attempt was made to project locations of power plants or specific source mines for plants in the importing states of South Dakota and Nebraska or for plants outside the boundaries of the study area.

Out-of-State Exports

Mine sites were projected under all three development forecasts, along with the expansion of existing mines, to supply the forecast demand for out-of-state exports. It was assumed that mines exporting coal will have capacities up to 10 MMtpy each. Depending upon equipment capabilities, overburden and coal characteristics, and economics, this may turn out to be a conservative figure.

An export mine will require an insignificant quantity of water in comparison to gasification and power generation facilities using some form of wet cooling. Therefore, proximity of a source of water was not a factor in the selection of mines for out-of-state export. However, proximity of existing or proposed railroad transportation networks was a factor, along with quality and quantity of the coal in the various deposits.

Those states importing coal will require coal from exporting states, but not necessarily from states within the study area. No attempt was made to relate export mines to the markets they will serve.

Household, Commercial, and Industrial

Coal requirements to supply the household, commercial, and industrial markets are insignificant in comparison to the three major market sectors previously discussed, and the market centers have not been defined. It was assumed that this demand for coal would be satisfied by small local mines or the expansion of existing mines. No actual siting criteria were involved in establishing the figures shown in the tabulation.

Siting Limitations

The validity of the mine-site projections is dependent upon the validity of the projections of coal demand in the Northern Great Plains Region as furnished by the Energy Work Group. The validity of siting is also dependent upon the accuracy of announcements by industry of potential mine sites or conversion plants. Because the Northern Great Plains Resource Program is intended merely ". . . to demonstrate the economic, social and environmental consequences of various courses of action," not a rigid plan for development, the validity of the projected demand and mine sites cannot be considered critical to the study in light of the extreme uncertainty of actual future development in the region. "The primary objective of the NGPRP is to provide an analytical and informational framework for policy and planning decisions at all levels of government." In this light, limitations of the mine siting will be discussed.

Gasification plant size of 250 MMscfd is supposedly the optimum size for the process of SNG manufacture at this time. The demand for

SNG and the mine sites projected to satisfy this demand are based upon the above plant size. Any change in plant size for commercial application will serve to modify SNG output and coal input. Also, the coal input requirements vary with the process under consideration. An average figure for coal requirements was assumed in the mine siting; therefore, some modification of the mine size will be necessary to match the process actually used. It is possible that the quality of the coal could negate use in a specific gasification process and thereby eliminate a selected site from consideration; however, this is an unknown variable and was not considered.

Although water was not quantitatively considered, the technology of process cooling could affect the location of gasification or steam-electric power generation plants, as well as the absolute number of plants. Air or combination wet-dry cooling could play an important role in the semiarid Northern Great Plains.

Advances in combustion technology which increase the efficiency of burning coal to produce electricity could reduce the feedstock requirements below that assumed for siting mines in this study. Also, advances in pollution technology and boiler design could alter requirements on the quality of coal burned for power generation. Only sulfur, ash, and heating value were considered in selecting sites for power generation. Other variables which affect boiler design may eliminate some sites from consideration.

Export mine size was assumed as being up to 10 MMtpy for convenience in siting, although mines as large as 30 million tons per year are feasible. Mines of such size will decrease the number of mines required to satisfy demand and therefore eliminate some projected sites. The primary consuming sector for out-of-state coal exports will be steam-electric power generation. Advances in pollution technology which permit the use of high-sulfur coal could significantly affect exports of coal out of the Northern Great Plains Region.

Two separate, but compatible, tabulations of projected mine sites are included with this report; they refer to sites shown on plates B-4, B-5, and B-6.

Base Forecast (Development Plan I)
(million tons)

Mine site	1971				1980				1985				2000			
	HCI1/	PWR2/	SNG3/	EXP4/	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Wyoming																
M-15/	-	0.4	-	0.3	-	1.2	-	0.3	-	1.2	-	0.3	-	1.2	-	0.3
M-2	-	-	-	-	-	-	-	9.5	-	-	-	9.5	-	-	-	9.5
M-3	(6/)	-	-	-	(6/)	-	-	-	(6/)	-	-	-	(6/)	-	-	-
M-4	-	1.8	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0	-	-
M-5	-	-	-	1.7	-	-	-	1.0	-	-	-	2.0	-	-	-	2.0
M-6	-	(6/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-7	-	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	3.0
M-8	-	-	-	-	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0
M-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-10	-	-	-	-	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0
P-17/	-	-	-	-	-	-	-	-	-	-	-	-	-	4.7	-	-
X-18/	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Total9/	(6/)	2.2	-	2.0	(6/)	4.2	-	24.8	(6/)	4.2	-	28.8	(6/)	8.9	-	30.8
Montana																
M-11	-	-	-	-	-	-	-	13.0	-	-	-	13.0	-	-	-	13.0
M-12	-	-	-	-	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0
M-13	-	-	-	1.5	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0
M-14	0.1	0.5	-	4.6	-	8.7	-	4.8	-	10.7	-	6.8	-	10.7	-	6.8
M-15	-	0.3	-	-	-	0.3	-	-	-	0.3	-	-	-	0.3	-	-
M-16	-	-	-	-	-	-	-	0.2	-	-	-	0.2	-	-	-	0.2
(M-17)																
10/(M-18)-	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
(M-19)																
P-2	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	-	-
P-3	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-	-
P-4	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	-	-
P-5	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-

Base Forecast (Development Plan I)--Continued

(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Montana--Continued																
X-2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Total	0.2	0.8	-	6.1	(6/)	9.0	-	26.0	(6/)	11.0	-	28.0	(6/)	26.6	-	30.0
North Dakota																
M-20	-	1.0	-	-	-	2.9	-	1.6	0.4	4.0	-	1.6	0.6	4.0	-	1.6
M-21	-	0.9	-	0.1	-	5.2	-	-	-	7.7	-	-	-	7.7	-	-
M-22	-	0.6	-	0.9	-	0.7	-	0.9	0.4	3.3	-	0.9	0.4	3.3	-	0.9
M-23	-	1.0	-	0.3	-	4.0	-	-	-	4.0	-	-	-	4.0	-	-
M-24	0.1	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-
M-25	-	(6/)	-	0.4	-	(6/)	-	0.5	-	(6/)	-	0.5	-	(6/)	-	0.5
M-26	-	-	-	0.2	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0
(M-27) 11/ (M-28) (M-29) (M-30)	0.2	-	-	-	0.2	-	-	-	0.2	-	-	-	-	-	-	-
P-6	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	-	-
X-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0
Total	0.3	3.5	-	2.3	0.2	12.8	-	6.0	1.0	19.0	-	6.0	1.0	24.7	-	8.0

1/ Household, commercial, and industrial sector demand.
2/ Electrical power generation sector demand.
3/ Synthetic natural gas sector demand.
4/ Export sector demand (exports out of NGPRP area).
5/ Planned or existing mines as shown on maps B-4, B-5, and B-6.
6/ Less than 100,000 tons; considered as insignificant for purposes of this study.
7/ Projected electrical power generation site as shown on map B-4.
8/ Projected export mine site as shown on map B-4.
9/ Totals for Wyoming are for NGPRP area only.
10/ Mines M-17, M-18, and M-19 were closed by 1972.
11/ Mine M-28 was closed by 1973.

Most Probable Forecast (Development Plan II)
(million tons)

Mine site	1971				1980				1985				2000			
	HCI[1/]	PWR[2/]	SNG[3/]	EXP[4/]	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Wyoming																
M-1[5/]	-	0.4	-	0.3	-	1.2	-	0.3	-	1.2	-	0.3	-	1.2	-	0.3
M-2	-	-	-	-	-	-	-	9.5	-	-	-	9.5	-	-	-	9.5
M-3	(6/)	-	-	-	(6/)	-	-	-	(6/)	-	-	-	(6/)	-	-	-
M-4	-	1.8	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0	-	-
M-5	-	-	-	1.7	-	-	-	1.0	-	-	-	2.0	-	-	-	2.0
M-6	-	(6/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-7	-	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	3.0
M-8	-	-	-	-	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0
M-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-10	-	-	-	-	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0
G-1[7/]	-	-	-	-	-	-	-	-	-	-	7.2	-	-	-	7.2	-
G-2	-	-	-	-	-	-	-	-	-	-	8.3	-	-	-	8.3	-
G-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.7	-
P-1[8/]	-	-	-	-	-	-	-	-	-	-	-	-	-	4.7	-	-
X-1[9/]	-	-	-	-	-	-	-	-	-	-	-	6.0	-	-	-	6.0
X-2	-	-	-	-	-	-	-	6.0	-	-	-	6.0	-	-	-	6.0
X-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.0
X-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.0
Total[10/]	(6/)	2.2	-	2.0	(6/)	4.2	-	30.8	(6/)	4.2	15.5	40.8	(6/)	8.9	24.2	58.8
Montana																
M-11	-	-	-	-	-	-	-	13.0	-	-	-	13.0	-	-	-	13.0
M-12	-	-	-	-	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0
M-13	-	-	-	1.5	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0
M-14	0.1	0.5	-	4.6	-	8.7	-	6.8	-	10.7	-	6.8	-	10.7	-	6.8
M-15	-	0.3	-	-	-	0.3	-	-	-	0.3	-	-	-	0.3	-	-
M-16	-	-	-	-	-	-	-	0.2	-	-	-	0.2	-	-	-	0.2

Most Probable Forecast (Development Plan II)--Continued

(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Montana--Continued																
(M-17) 11/(M-18)- (M-19)	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G-4	-	-	-	-	-	-	-	-	-	-	7.1	-	-	-	7.1	-
G-5	-	-	-	-	-	-	-	-	-	-	7.2	-	-	-	7.2	-
G-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.0	-
G-7	-	-	-	-	-	-	-	-	-	-	7.9	-	-	-	7.9	-
G-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.9	-
G-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2	-
P-2	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	-	-
P-3	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-	-
P-4	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	-	-
P-5	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-
X-5	-	-	-	-	-	-	-	4.0	-	-	-	6.0	-	-	-	6.0
X-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.5
X-7	-	-	-	-	-	-	-	-	-	-	-	7.0	-	-	-	7.0
X-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.5
Total	0.2	0.8	-	6.1	(6/)	9.0	-	32.0	(6/)	11.0	22.2	41.0	(6/)	26.6	46.3	60.0
North Dakota																
M-20	-	1.0	-	-	-	2.9	-	1.6	0.4	4.0	-	1.6	0.6	4.0	-	1.6
M-21	-	0.9	-	0.1	-	5.2	-	-	-	7.7	-	-	-	7.7	-	-
M-22	-	0.6	-	0.9	-	0.7	-	0.9	0.4	3.3	-	0.9	0.4	3.3	-	0.9
M-23	-	1.0	-	0.3	-	4.0	-	-	-	4.0	-	-	-	4.0	-	-
M-24	0.1	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-
M-25	-	(6/)	-	0.4	-	(6/)	-	0.5	-	(6/)	-	0.5	-	(6/)	-	0.5
M-26	-	-	-	0.2	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0

Most Probable Forecast (Development Plan II)--Continued

(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
North Dakota--Continued																
12/ (M-27) (M-28) (M-29) (M-30)	0.2	-	-	-	0.2	-	-	-	0.2	-	-	-	-	-	-	-
G-10	-	-	-	-	-	-	-	-	-	-	10.1	-	-	-	10.1	-
G-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-13	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0	-
G-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-
G-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.7	-
G-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.7	-
P-6	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	-	-
P-7	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	-	-
P-8	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	-	-
P-9	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	-	-
P-10	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	-	-
P-11	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	-	-
X-9	-	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	6.0
Total	0.3	3.5	-	2.3	0.2	12.8	-	6.0	1.0	19.0	20.1	9.0	1.0	56.6	69.7	12.0

1/ Household, commercial, and industrial sector demand.
2/ Electrical power generation sector demand.
3/ Synthetic natural gas sector demand.
4/ Export sector demand (exports out of NGPRP area).
5/ Planned or existing mines as shown on maps B-4, B-5, and B-6.
6/ Less than 100,000 tons; considered as insignificant for purposes of this study.
7/ Projected SNG plant site as shown on map B-5.
8/ Projected electrical power generation site as shown on map B-5.
9/ Projected export mine site as shown on map B-5.
10/ Totals for Wyoming are for NGPRP area only.
11/ Mines M-17, M-18, and M-19 were closed by 1972.
12/ Mine M-28 was closed by 1973.

Extensive Development Forecast (Development Plan III)
(million tons)

Mine site	1971				1980				1985				2000			
	HCI[1]	PWR[2]	SNG[3]	EXP[4]	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Wyoming																
M-1[5]	-	0.4	-	0.3	-	1.2	-	0.3	-	1.2	-	0.3	-	1.2	-	0.3
M-2	-	-	-	-	-	-	-	9.5	-	-	-	9.5	-	-	-	9.5
M-3	(6/)	-	-	-	(6/)	-	-	-	(6/)	-	-	-	(6/)	-	-	-
M-4	-	1.8	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0	-	-
M-5	-	-	-	1.7	-	-	-	1.0	-	-	-	2.0	-	-	-	2.0
M-6	-	(6/)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M-7	-	-	-	-	-	-	-	-	-	-	-	3.0	-	-	-	3.0
M-8	-	-	-	-	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0
M-9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0
M-10	-	-	-	-	-	-	-	7.0	-	-	-	7.0	-	-	-	7.0
G-1[7]	-	-	-	-	-	-	-	-	-	-	8.5	-	-	-	8.5	-
G-2	-	-	-	-	-	-	-	-	-	-	8.3	-	-	-	8.3	-
G-3	-	-	-	-	-	-	-	-	-	-	8.3	-	-	-	8.3	-
G-4	-	-	-	-	-	-	-	-	-	-	8.3	-	-	-	8.3	-
G-5	-	-	-	-	-	-	-	-	-	-	8.3	-	-	-	8.3	-
G-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.3	-
G-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.7	-
G-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.7	-
G-9	-	-	-	-	-	-	-	-	-	-	8.7	-	-	-	8.7	-
P-1[8]	-	-	-	-	-	-	-	-	-	-	-	-	-	4.7	-	-
X-1[9]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-2	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-5	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-9	-	-	-	-	-	-	-	6.0	-	-	-	10.0	-	-	-	10.0

Extensive Development Forecast (Development Plan III)--Continued

(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Wyoming--Continued																
X-10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-18	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-20	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
Total[10]	(6/)	2.2	-	2.0	(6/)	4.2	-	30.8	(6/)	4.2	50.4	78.8	(6/)	8.9	76.1	275.8
Montana																
M-11	-	-	-	-	-	-	-	13.0	-	-	-	13.0	-	-	-	13.0
M-12	-	-	-	-	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0
M-13	-	-	-	1.5	-	-	-	4.0	-	-	-	4.0	-	-	-	4.0
M-14	0.1	0.5	-	4.6	-	8.7	-	6.8	-	10.7	-	6.8	-	10.7	-	6.8
M-15	-	0.3	-	-	-	0.3	-	-	-	0.3	-	-	-	0.3	-	-
M-16	-	-	-	-	-	-	-	0.2	-	-	-	0.2	-	-	-	0.2
(M-17) [12](M-18)- (M-19)	0.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G-10	-	-	-	-	-	-	7.1	-	-	-	7.1	-	-	-	7.1	-
G-11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.1	-
G-12	-	-	-	-	-	-	-	-	-	-	7.2	-	-	-	7.2	-

Extensive Development Forecast (Development Plan III)--Continued

(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Montana--Continued																
G-13	-	-	-	-	-	-	-	-	-	-	8.0	-	-	-	8.0	-
G-14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.0	-
G-15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.0	-
G-16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.0	-
G-17	-	-	-	-	-	-	-	-	-	-	8.2	-	-	-	8.2	-
G-18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2	-
G-19	-	-	-	-	-	-	7.9	-	-	-	7.9	-	-	-	7.9	-
G-20	-	-	-	-	-	-	-	-	-	-	7.9	-	-	-	7.9	-
G-21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.9	-
G-22	-	-	-	-	-	-	-	-	-	-	8.4	-	-	-	8.4	-
G-23	-	-	-	-	-	-	8.2	-	-	-	8.2	-	-	-	8.2	-
G-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.2	-
P-2	-	-	-	-	-	-	-	-	-	-	-	-	-	3.5	-	-
P-3	-	-	-	-	-	-	-	-	-	-	-	-	-	3.9	-	-
P-4	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	-	-
P-5	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	-	-
X-25	-	-	-	-	-	-	-	4.0	-	-	-	9.0	-	-	-	9.0
X-26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-28	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-32	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-34	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-37	-	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0
X-38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0

Extensive Development Forecast (Development Plan III)--Continued
(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
Montana--Continued																
X-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
X-46	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0
Total	0.2	0.8	-	6.1	(6/)	9.0	23.2	32.0	(6/)	11.0	62.9	77.0	(6/)	26.6	118.3	247.0
North Dakota[11/]																
M-20	-	1.0	-	-	-	2.9	-	1.6	0.4	4.0	-	1.6	0.6	4.0	-	1.6
M-21	-	0.9	-	0.1	-	5.2	-	-	-	7.7	-	-	-	7.7	-	-
M-22	-	0.6	-	0.9	-	0.7	-	0.9	0.4	3.3	-	0.9	0.4	3.3	-	0.9
M-23	-	1.0	-	0.3	-	4.0	-	-	-	4.0	-	-	-	4.0	-	-
M-24	0.1	-	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-
M-25	-	(6/)	-	0.4	-	(6/)	-	0.5	-	(6/)	-	0.5	-	(6/)	-	0.5
M-26	-	-	-	0.2	-	-	-	3.0	-	-	-	3.0	-	-	-	3.0
13/ (M-27) (M-28) (M-29) (M-30)	0.2	-	-	-	0.2	-	-	-	0.2	-	-	-	-	-	-	-
G-25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.9	-
G-26	-	-	-	-	-	-	10.1	-	-	-	10.1	-	-	-	10.1	-
G-27	-	-	-	-	-	-	10.1	-	-	-	10.1	-	-	-	10.1	-
G-28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.1	-
G-33	-	-	-	-	-	-	10.0	-	-	-	10.0	-	-	-	10.0	-
G-34	-	-	-	-	-	-	10.0	-	-	-	10.0	-	-	-	10.0	-

Extensive Development Forecast (Development Plan III)--Continued

(million tons)

Mine site	1971				1980				1985				2000			
	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP	HCI	PWR	SNG	EXP
North Dakota--Continued																
G-35	-	-	-	-	-	-	-	-	-	-	10.0	-	-	-	10.0	-
G-36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-
G-37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	10.0	-
G-39	-	-	-	-	-	-	-	-	-	-	9.7	-	-	-	9.7	-
G-40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.7	-
G-41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9.7	-
G-42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.5	-
P-6	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	-	-
P-7	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	-	-
P-8	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8	-	-
P-9	-	-	-	-	-	-	-	-	-	-	-	-	-	6.5	-	-
P-10	-	-	-	-	-	-	-	-	-	-	-	-	-	5.7	-	-
P-11	-	-	-	-	-	-	-	-	-	-	-	-	-	5.9	-	-
X-47	-	-	-	-	-	-	-	-	-	-	-	4.0	-	-	-	6.0
X-48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0
Total	0.3	3.5	-	2.3	0.2	12.8	40.2	6.0	1.0	19.0	59.9	10.0	1.0	56.6	172.2	18.0

1/ Household, commercial, and industrial sector demand.
2/ Electrical power generation sector demand.
3/ Synthetic natural gas sector demand.
4/ Export sector demand (exports out of NGPRP area).
5/ Planned or existing mines as shown on maps B-4, B-5, and B-6.
6/ Less than 100,000 tons; considered as insignificant for purposes of this study.
7/ Projected SNG plant site as shown on map B-6.
8/ Projected electrical power generation site as shown on map B-6.
9/ Projected export mine site as shown on map B-6.
10/ Totals for Wyoming are for NGPRP area only.
11/ SNG site number 38 should be removed from map B-6 if present.
12/ Mines M-17, M-18, and M-19 were closed by 1972.
13/ Mine M-28 was closed by 1973.

Base Forecast (Development Plan I) - Map B-4

Power Generation

Map ref. No.	County	Target year	Capactiy (Megawatts)	Mine size (MMtpy)	Average Btu/lb
		- Wyoming -			
1	Campbell	2000	1200	4.7	8300
		- Montana -			
2	Big Horn	2000	1025	3.5	9650
3	Do.	2000	1025	3.9	8450
4	Rosebud	2000	1025	3.8	8850
5	McCone	2000	1025	4.4	7660
		- North Dakota -			
6	Mercer	2000	1200	5.7	6870

Export

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb	Average sulfur (%)
		- Wyoming -			
1	Campbell	2000	2.0	8320	0.5
		- Montana -			
2	Big Horn	2000	2.0	9600	0.4
		- North Dakota -			
3	Slope	2000	2.0	5960	0.9

Most Probable Forecast (Development Plan II) - Map B-5

Gasification

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb
		- Wyoming -		
1	Converse	1985	7.2	9500
2	Campbell	1985	8.3	8320
3	Johnson	2000	8.7	7940
		- Montana -		
4	Big Horn	1985	7.1	9650
5	Do.	1985	7.2	8000
7	Rosebud	1985	7.9	8700
6	Big Horn	2000	8.0	8600
8	Rosebud	2000	7.9	8700
9	Powder River	2000	8.2	8400
		- North Dakota -		
10	Dunn	1985	10.1	6800
13	Mercer	1985	10.0	6900
11	Dunn	2000	10.1	6800
12	Do.	2000	10.1	6800
14	Mercer	2000	10.0	6900
15	McLean	2000	9.7	7100
16	Do.	2000	9.7	7100

Note.--A substantial amount of fine coal (-1/8") is generated in mining and processing lignite before it reaches a gasification plant, and, if the Lurgi process is used, the less than 1/8-inch coal is not suitable for the process. An additional tonnage would have to be mined to allow for the less than 1/8-inch coal, or a briquetting plant would be required.

Most Probable Forecast (Development Plan II) - Map B-5 - Con.

Power Generation

Map ref. No.	County	Target year	Capacity (Megawatts)	Mine size (MMtpy)	Average Btu/lb
		- Wyoming -			
1	Campbell	2000	1200	4.7	8300
		- Montana -			
2	Big Horn	2000	1025	3.5	9650
3	Do.	2000	1025	3.9	8450
4	Rosebud	2000	1025	3.8	8850
5	McCone	2000	1025	4.4	7660
		- North Dakota -			
6	Slope	2000	1250	5.9	6870
7	Hettinger	2000	1250	6.8	6000
8	Do.	2000	1250	6.8	6000
9	Billings	2000	1250	6.5	6280
10	Oliver	2000	1250	5.7	7070
11	Mercer	2000	1250	5.9	6870

Most Probable Forecast (Development Plan II) - Map B-5 - Con.

Export

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb	Average Sulfur (%)
		- Wyoming -			
2	Campbell	1980	6.0	8320	0.5
1	Campbell	1985	6.0	8100	0.5
3	Campbell	2000	9.0	8300	0.5
4	Sheridan	2000	9.0	9500	0.5
		- Montana -			
5	Big Horn	1980	4.0	9600	0.4
5	Big Horn	1985	6.0	9600	0.4
7	Rosebud	1985	7.0	8800	0.4
6	Powder River	2000	9.5	8200	0.3
8	Rosebud	2000	9.5	8500	0.3
		- North Dakota -			
9	Slope	1985	3.0	5960	0.9
9	Slope	2000	6.0	5960	0.9

Extensive Development Forecast (Development Plan III) - Map B-6

Gasification

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb
		- Wyoming -		
1	Converse	1985	8.5	8100
2	Campbell	1985	8.3	8320
3	Do.	1985	8.3	8320
4	Do.	1985	8.3	8320
5	Do.	1985	8.3	8320
9	Johnson	1985	8.7	7940
6	Campbell	2000	8.3	8320
7	Johnson	2000	8.7	7940
8	Do.	2000	8.7	7940
		- Montana -		
10	Big Horn	1980	7.1	9650
19	Rosebud	1980	7.9	8700
23	Powder River	1980	8.2	8400
12	Big Horn	1985	7.2	8000
13	Do.	1985	8.0	8600
17	Rosebud	1985	8.2	8400
20	Do.	1985	7.9	8700
22	Do.	1985	8.4	8170
11	Big Horn	2000	7.1	9650
14	Do.	2000	8.0	8600
15	Do.	2000	8.0	8600
16	Do.	2000	8.0	8600
18	Rosebud	2000	8.2	8400
21	Do.	2000	7.9	8700
24	Powder River	2000	8.2	8400
		- North Dakota -		
26	Dunn	1980	10.1	6800
27	Do.	1980	10.1	6800
33	Mercer	1980	10.0	6900
34	Do.	1980	10.0	6900

Extensive Development Forecast (Development Plan III) - Map B-6 - Con.

Gasification--Con.

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb
		- North Dakota (Con.) -		
35	Mercer	1985	10.0	6900
39	McLean	1985	9.7	7100
25	Stark	2000	10.9	6280
28	Dunn	2000	10.1	6800
29	Do.	2000	10.1	6800
30	Do.	2000	10.1	6800
31	Do.	2000	10.1	6800
32	Do.	2000	10.1	6800
36	Mercer	2000	10.0	6900
37	Do.	2000	10.0	6900
40	McLean	2000	9.7	7100
41	Do.	2000	9.7	7100
42	Slope	2000	11.5	6000

Power Generation

Map ref. No.	County	Target year	Capacity (Megawatts)	Mine size (MMtpy)	Average Btu/lb
			- Wyoming -		
1	Campbell	2000	1200	4.7	8300
			- Montana -		
2	Big Horn	2000	1025	3.5	9650
3	Do.	2000	1025	3.9	8450
4	Rosebud	2000	1025	3.8	8350
5	McCone	2000	1025	4.4	7660
			- North Dakota -		
6	Slope	2000	1250	5.9	6870
7	Hettinger	2000	1250	6.8	6000
8	Do.	2000	1250	6.8	6000
9	Billings	2000	1250	6.5	6280
10	Oliver	2000	1250	5.7	7070
11	Mercer	2000	1250	5.9	6870

Extensive Development Forecast (Development Plan III) - Map B-6 - Con.

Export

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb	Average sulfur (%)
		- Wyoming -			
9	Campbell	1980	6.0	8320	0.5
9	Campbell	1985	10.0	8320	0.5
2	Do.	1985	10.0	9000	0.6
5	Do.	1985	10.0	8600	0.6
18	Do.	1985	10.0	8300	0.5
20	Do.	1985	10.0	9500	0.5
1	Converse	2000	10.0	9000	0.7
3	Campbell	2000	10.0	8600	0.6
4	Do.	2000	10.0	8600	0.6
6	Do.	2000	10.0	8500	0.5
7	Do.	2000	10.0	8500	0.5
8	Do.	2000	10.0	8500	0.5
10	Do.	2000	10.0	8320	0.5
11	Do.	2000	10.0	8320	0.5
12	Do.	2000	10.0	8320	0.5
13	Do.	2000	10.0	8320	0.5
14	Do.	2000	10.0	8320	0.5
15	Do.	2000	10.0	8320	0.5
16	Do.	2000	10.0	8320	0.5
17	Do.	2000	10.0	8320	0.5
19	Do.	2000	10.0	8300	0.5
21	Sheridan	2000	10.0	9500	0.5
22	Johnson	2000	10.0	7940	0.7
23	Do.	2000	10.0	7940	0.7
24	Sheridan	2000	10.0	9500	0.5
		- Montana -			
25	Big Horn	1980	4.0	9600	0.4
25	Big Horn	1985	9.0	9600	0.4
28	Do.	1985	10.0	7640	0.3
32	Rosebud	1985	10.0	8800	0.4
34	Do.	1985	10.0	8500	0.3
37	Powder River	1985	10.0	8200	0.3

Extensive Development Forecast (Development Plan III) - Map B-6 - Con.

Export--Con.

Map ref. No.	County	Target year	Mine size (MMtpy)	Average Btu/lb	Average sulfur (%)
			- Montana (Con.) -		
26	Big Horn	2000	10.0	9600	0.4
27	Do.	2000	10.0	9600	0.4
29	Do.	2000	10.0	8450	0.3
30	Do.	2000	10.0	8450	0.3
31	Do.	2000	10.0	8390	0.4
33	Rosebud	2000	10.0	8470	0.4
35	Do.	2000	10.0	8400	0.4
36	Do.	2000	10.0	8400	0.4
38	Powder River	2000	10.0	8200	0.3
39	Do.	2000	10.0	8470	0.4
40	Do.	2000	10.0	8370	0.2
41	Do.	2000	10.0	8370	0.2
42	Do.	2000	10.0	7440	0.3
43	Do.	2000	10.0	7440	0.4
44	Custer	2000	10.0	7600	0.5
45	Do.	2000	10.0	7600	0.5
46	Do.	2000	10.0	6690	0.4
			- North Dakota -		
47	Slope	1985	4.0	5960	0.9
47	Slope	2000	6.0	5960	0.9
48	Oliver	2000	6.0	7000	0.8

COAL RESOURCES AND RESERVES

Introduction

The Northern Great Plains Region contains about 46 percent of the estimated remaining coal resources of the United States as of January 1, 1972. This very large percentage is contained in a compact area of 84,000 square miles, which represents only 18 percent of the total area of coal-bearing rock in the United States. The relation of 46 percent of the tonnage in 18 percent of the area of coal-bearing rock provides very convincing evidence of the concentration of coal in the Northern Great Plains. This concentration is explained primarily by the greater thickness of individual coalbeds in the Northern Great Plains Region as compared to the thickness of coalbeds in other parts of the United States.

The coal in the Northern Great Plains Region occurs in a sequence of beds, 1,500 to 3,000 feet thick, of late Cretaceous to Eocene age. This sequence is divided from bottom to top into the Hell Creek, Tullock, Fort Union, and Wasatch formations. The coal resources are concentrated in the Fort Union formation of Paleocene age, and only subordinate amounts are present in the underlying and overlying formations.

The rocks associated with the coal consist primarily of poorly consolidated sandstone and siltstone, with minor amounts of shale. Many of the coal outcrops have been ignited by spontaneous combustion, forest fires, lightning, and acts of man. Areas this affected are characterized by the red color of the baked rocks over the burned-out coal. These baked rocks are locally termed "clinker," but in this report are referred to as "baked shale." Some of the burning took place thousands of years ago; some is of recent origin.

Table 1 shows the estimated total coal resources of the Northern Great Plains Region by states and by several major coal resource categories. The resource estimates were calculated as of June 1973. Additional surface minable resources totaling approximately 10 billion tons have been identified in eastern Montana since that date. Column 1 in the tables includes coal in a choice category termed "reserves" and defined as "measured and indicated coal in thick and intermediate beds, generally 1,000 feet or less below the surface." The coal in this category is in beds 5 feet thick or more. Column 2 in the table includes: (1) inferred resources; (2) resources in beds less than 5 feet thick; and (3) all resources with more than 1,000 feet of overburden. This larger tonnage has been excluded from column 1 because it is not of current interest. Column 3, the sum of columns 1 and 2, represents total identified resources based on geologic mapping of coal areas and many measurements of coal thickness. Column 4, hypothetical resources, represents estimated tonnages in unmapped and unexplored parts of coal field areas, based on extrapolations from nearby areas of identified resources. Column 5, total estimated resources, is the sum of columns 3 and 4. The figures in column 5 show that the part of the Powder River Basin in Wyoming contains the largest total coal resources, followed in order by North Dakota and eastern Montana. The resources of South Dakota are small by comparison.

The totals in table 1 show that the hypothetical resources of the Northern Great Plains Region represent about 55 percent of total

Table 1. - Estimated total coal resources of the Northern Great Plains Region
(In millions of short tons. All figures are for coal in the ground, no more than half of which may be considered recoverable.)

State	Identified resources		Total identified resources	Additional hypothetical resources in unmapped and unexplored areas	Total estimated resources
	Original or remaining reserves. Includes measured and indicated resources in beds 5 ft. or more thick, and less than 1,000 ft. below the surface.	Inferred resources; resources in beds generally less than 5 ft. thick; and resources with more than 1,000 ft. overburden.			
	(1)	(2)	(3)=(1)+(2)	(4)	(5)=(3)+(4)
Montana1/	158,078	61,428	219,506	155,000	374,506
Wyoming2/	34,722	75,583	110,305	500,000	610,305
North Dakota3/	37,453	313,457	350,910	180,000	530,910
South Dakota4/	1,021	1,166	2,187	---	2,187
Total	231,274	451,634	682,908	835,000	1,517,908

1/ Original resources; eastern Montana and Bull Mountain field. See table 2.
2/ Remaining resources, Jan. 1, 1972; Powder River Basin in Wyoming. See table 4.
3/ Original resources. See table 6.
4/ Original resources. See table 8.

resources, which suggests a substantial potential for change in the figures in columns 1, 2, and 3 as new resource information is obtained in the future.

Past Production

Throughout the years, production of coal in the Northern Great Plains has been minimal by national standards. In 1965, for example, the region produced about 5 million tons, or 1 percent of the national total of 512 million tons. In 1972, the region produced about 20 million tons or about 3.3 percent of the national total of 595 million tons. This may be compared to 1972 production of 144 million tons, or 24 percent of total national production, from the Illinois coal basin of Illinois, Indiana, and western Kentucky, which is only half the size of the Northern Great Plains coal-bearing region and contains only one-fourth as much coal.

Structure of coal-bearing rocks

The coal-bearing rocks of the Northern Great Plains Region are nearly flat-lying. Throughout most of the region, for example, measurable dips are only 1 to 2 degrees. However, these low dips are locally reversed and give rise to three broad regional structural features: (1) the Williston Basin, centered in western North Dakota; (2) the Cedar Creek anticline, near the Montana-North Dakota line; and (3) the Powder River Basin in northeastern Wyoming and southeastern Montana. The steepest dips, commonly 5 to 10 degrees eastward, are along the western edge of the Powder River Basin in north-central Wyoming.

Because of the gentle dips, and the reversals of dip associated with the three structural features mentioned above, the coal-bearing rocks are near the surface in most parts of the Northern Great Plains Region. In the deepest part of the Powder River Basin in Wyoming, the coal-bearing rocks are a little more than 2,000 feet below the surface, but are less than 2,000 feet below the surface over most of the Wyoming part of the basin. In eastern Montana, most of the coal is less than 1,500 feet below the surface. In North Dakota, all of the coal is less than 1,200 feet below the surface, and 98 percent is less than 1,000 feet below the surface. In South Dakota, all of the coal is less than 1,000 feet below the surface, and about 80 percent is less than 500 feet below the surface.

The Bull Mountain field, which lies mainly in Musselshell and Yellowstone Counties, Mont., is a broad, shallow basin with a northwest-trending synclinal axis. Throughout most of the basin, the coal-bearing rocks dip 1 to 5 degrees toward the center of the basin, but are nearly flat to the east and south, and are steeper to the north. In the northwest part of the basin, the dip steepens to a maximum of 30 degrees. Most of past and current mining has been in the broad, central part of the basin where dips are low.

Distribution of Resources by States and Counties

The distribution of estimated total coal resources of the Northern Great Plains Region by states has been presented in table 1. A further breakdown of resources by individual counties in eastern Montana, northeastern Wyoming, North Dakota, and South Dakota is presented in tables 2, 4, 6, and 8, respectively. The method of recovery, surface versus underground, is presented in companion tables 3, 5, 7, and 9, and is discussed under the next heading. Tables 2, 4, 6, and 8 show the very substantial concentration of identified resources (column 3 in each table) in Dunn County, N. Dak.; Campbell County, Wyo.; Big Horn County, Mont.; and Rosebud County, Mont.; and the significant concentrations in surrounding counties in the three states. The primary sources of information for the estimates of identified resources in tables 2, 4, 6, and 8 were published in the period 1949-1953. New information assembled since that period suggests that the estimates of identified resources are conservative. The estimates of hypothetical resources and of total resources (columns 4 and 5 in tables 2, 4, and 6) show the larger totals that are probably present in the three respective states.

Because coal is widespread and abundant in the Northern Great Plains Region, current economic interest is centered on coal in the "reserve" category. The tonnage in this choice category is presented in column 1 of tables 1-9, inclusive.

The tonnage of coal included in the "reserve" category is also conservative. The "inferred" category, for example, which is included in column 2 of tables 2, 4, 6, and 8, obviously includes coal in thick beds that are remote from outcrops or points of reliable information. In the future, therefore, with an expectable increase in the amount and reliability of data, the tonnages in column 1 of each table can certainly be increased by a shift of tonnages from column 2, and in

Table 2.--Estimated original coal resources of eastern Montana.[1] [In millions of short tons. Overburden 0-1,500 ft.[2] All figures are for coal in the ground. Recoverability of tonnage in column 1 is discussed in table 3.]

County	Original reserves in the ground[3] (1)	Inferred resources and resources in beds less than 5 ft thick (2)	Total identified resources (3)=(1)+(2)	Additional hypothetical resources in unmapped and unexplored areas (4)	Total estimated resources (5)=(3)+(4)
			Subbituminous coal		
Big Horn	38,355	5,146	43,501		
Garfield	137	476	613		
Musselshell[4]	3,467	4	3,471		
Rosebud	26,274	12,610	38,884		
Treasure	1,304	---	1,304		
Yellowstone[4]	590	---	590		
Total	70,127	18,236	88,363		
			Subbituminous coal and lignite[5]		
Custer	3,463	1,415	4,878		
McCone	24,501	371	24,872		
Powder River	28,074	15,343	43,417		
Prairie	1,045	536	1,581		
Total	57,083	17,665	74,748		
			Lignite		
Carter	56	407	463		
Daniels	3,965	---	3,965		
Dawson	8,332	2,779	11,111		
Fallon	1,622	922	2,544		
Richland	8,068	13,017	21,085		
Roosevelt	1,632	2,532	4,164		
Sheridan	5,069	695	5,764		
Valley	258	---	258		
Wibaux	1,866	5,175	7,041		
Total	30,868	25,527	56,395		
Grand total	158,078	61,428	219,506	155,000[6]	374,506
Cumulative production and losses in mining to Jan. 1, 1972[7].............					224
Resources remaining in the ground, Jan. 1, 1972..........................					374,282

[1] From Combo and others (1949). Since the summary report by Combo and others was prepared, additional mapping and drilling, particularly in the investigation of stripping coal deposits, suggests that the estimate of identified tonnage in eastern Montana should be increased about 70 billion tons. However, this additional tonnage cannot readily be integrated with the tonnage reported by Combo and others because, for the most part, it is not classified in the same detail.

[2] Most of the coal in eastern Montana is 1,500 feet or less below the surface.

[3] Measured and indicated resources in thick and intermediate beds plus coal unclassified as to thickness but known to be mostly in thick beds. Includes coal in beds 5 feet or more thick.

[4] Bull Mountain field.

[5] Subbituminous coal in western part of county, lignite in eastern part. However, difference in rank across these counties is slight.

[6] Not classified by county.

[7] Assuming past losses in mining equal past production.

Table 3.--Method of recovery of coal reserves of eastern Montana, Jan. 1, 1972.

[In millions of short tons]

County	Original reserves in the ground[1] (1)	Method of recovery				
		Surface mining			Underground mining	
		Reserves in the ground[2] (2)	Potentially recoverable[3] (3)	Economically recoverable[4] (4)	Reserves in the ground[5] (5)	Potentially recoverable[6] (6)
Subbituminous coal						
Big Horn	38,355	8,200	6,600	3,960	30,155	15,078
Garfield	137	12	10	6	125	62
Musselshell[7]	3,467	110	90	54	3,357	1,679
Rosebud	26,274	5,620	4,500	2,700	20,654	10,327
Treasure	1,304	280	220	130	1,024	512
Yellowstone[7]	590	---	---	---	590	295
Total	70,127	14,222	11,420	6,850	55,905	27,953
Subbituminous coal and lignite[8]						
Custer	3,463	2,200	1,760	1,060	1,263	632
McCone	24,501	1,140	910	550	23,361	11,680
Powder River	28,074	10,250	8,200	4,920	17,824	8,912
Prairie	1,045	---	---	---	1,045	522
Total	57,083	13,590	10,870	6,530	43,493	21,746
Lignite						
Carter	56	---	---	---	56	28
Daniels	3,965	---	---	---	3,965	1,983
Dawson	8,332	1,200	960	580	7,132	3,566
Fallon	1,622	150	120	70	1,472	736
Richland	8,068	900	720	430	7,168	3,584
Roosevelt	1,632	431	340	200	1,201	600
Sheridan	5,069	454	360	220	4,615	2,307
Valley	258	---	---	---	258	129
Wibaux	1,866	910	730	440	956	478
Total	30,868	4,045	3,230	1,940	26,823	13,411
Grand total	158,078	31,857	25,520	15,320	126,221	63,110

[1] From col. 1, table . Cumulative production and losses to Jan. 1, 1972 is small and not well recorded by county or rank of coal. Use of available figures for original reserves introduces no appreciable error.

[2] From R. E. Matson and J. W. Blumer, Montana Bureau of Mines and Geology. See also U.S. Bur. Mines (1969; 1971a); Matson and Blumer (In press).

[3] 80% of figures in col. 2.

[4] 60% of figures in col. 3.

[5] Col. 2 plus col. 5 equals col. 1.

[6] 50% of figures in col. 5.

[7] Bull Mountain field.

[8] Subbituminous coal in western part of county, lignite in eastern part. However, difference in rank across these counties is slight.

Table 4.--Estimated remaining coal resources of the Powder River Basin, Wyoming, Jan. 1, 1972.[1] [In millions of short tons. All figures are for coal in the ground. Recoverability of tonnage in column 1 is discussed in table 5.]

County	Remaining reserves in the ground, 0-1,000 ft overburden, Jan. 1, 1972[2] (1)	Inferred resources in thin beds, 0-1,000 ft overburden; and identified resources in all beds, 1,000-3,000 ft overburden (2)	Total remaining identified resources, 0-3,000 ft overburden (3)=(1)+(2)	Additional hypothetical resources in unmapped and unexplored areas, 0-3,000 ft overburden [3] (4)	Total remaining resources, 0-3,000 ft overburden (5)=(3)+(4)
Subbituminous coal					
Campbell	25,000	44,018	[4] 69,018		
Converse	1,636	2,497	4,133		
Crook	Neg.	8	8		
Johnson	3,000	9,235	[4] 12,235		
Natrona	35	158	193		
Niobrara	Neg.	14	14		
Sheridan	5,000	19,390	[4] 24,390		
Weston	36	244	280		
Total	34,707	75,564	110,271	[3] 500,000	610,271
Bituminous coal					
Crook	1	1	2	0	2
Weston	14	18	32	0	32
Total	15	19	34	0	34
Grand total	34,722	75,583	110,305	[3] 500,000	610,305

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[1] From Berryhill and others (1950) except as noted.

[2] Measured and indicated identified resources in thick and intermediate beds, 0-1,000 ft overburden. Includes subbituminous coal and lignite in beds 5 feet or more thick, and bituminous coal in beds 28 inches or more thick.

[3] Based on data in Wold and Woodward (1968). Not classified by county.

[4] From Glass (1972).

Table 5.--Method of recovery of remaining coal reserves of the Powder River Basin, Wyoming, Jan. 1, 1972. [In millions of short tons]

County	Remaining reserves in the ground, 0-1,000 ft over-burden, Jan. 1, 1972[1] (1)	Method of recovery				
		Surface mining[2]			Underground mining	
		Reserves in the ground[3] (2)	Potentially recoverable[4] (3)	Economically recoverable[2] (4)	Reserves in the ground[3] (5)	Potentially recoverable[5] (6)
			Subbituminous coal			
Campbell	25,000	16,900	13,520	12,100	8,100	4,050
Converse	1,636	810	648	250	826	413
Crook	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Johnson	3,000	2,000	1,600	800	1,000	500
Natrona	35	Neg.	Neg.	Neg.	35	17
Niobrara	Neg.	Neg.	Neg.	Neg.	Neg.	Neg.
Sheridan	5,000	140	112	112	4,860	2,430
Weston	36	Neg.	Neg.	Neg.	36	18
Total	34,707	19,850	15,880	13,262	14,857	7,428
			Bituminous coal			
Crook	1	0	0	0	1	Neg.
Weston	14	0	0	0	14	7
Total	15	0	0	0	15	7
Grand total	34,722	19,850	15,880	13,262	14,872	7,435

[1] From. col. 1, table 4 .
[2] From U.S. Bur. Mines (1971 a, b).
[3] Col. 2 plus col. 5 equals col. 1
[4] 80% of figures in col. 2.
[5] 50% of figures in col. 5.

Table 6.--Estimated original lignite resources of North Dakota.[1] [In millions of short tons. Overburden 0-1,200 feet.[2] All figures are for lignite in the ground. Recoverability of tonnage in column 1 is discussed in table 7.]

County	Original reserves in the ground[3] (1)	Inferred resources and resources in beds less than 5 ft thick (2)	Total identified resources (3)=(1)+(2)	Additional hypothetical resources in unmapped and unexplored areas (4)	Total estimated resources (5)=(3)+(4)
Adams	266	1,591	1,857		
Billings	2,836	14,882	17,718		
Bowman	1,136	5,885	7,021		
Burke	530	6,080	6,610		
Burleigh	208	949	1,157		
Divide	792	7,472	8,264		
Dunn	2,992	68,050	71,042		
Golden Valley	1,290	7,029	8,319		
Grant	670	3,988	4,658		
Hettinger	1,847	10,806	12,653		
McHenry	40	78	118		
McKenzie	3,211	28,972	32,183		
McLean	1,923	14,555	16,478		
Mercer	4,754	25,159	29,913		
Morton	1,968	13,282	15,250		
Montrail	749	14,629	15,378		
Oliver	1,923	15,916	17,839		
Renville	59	724	783		
Sheridan	---	660	660		
Slope	4,994	15,097	20,091		
Stark	2,216	23,481	25,697		
Ward	905	9,381	10,286		
Williams	2,144	24,791	26,935		
Total	37,453	313,457	350,910	[4] 180,000	530,910
Cumulative production and losses in mining to Jan. 1, 1972[5].............					280
Resources remaining in the ground, Jan. 1, 1972..........................					530,630

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[1] From Brant (1953), with minor modification of data for Hettinger County.

[2] About 98 percent of the total lignite in North Dakota is 1,000 feet or less below the surface.

[3] Measured and indicated resources in beds 5 feet or more thick.

[4] Not classified by county.

[5] Assuming past losses in mining equal past production.

Table 7.--Method of recovery of lignite reserves of North Dakota, Jan. 1, 1972

[In millions of short tons]

County	Original reserves in the ground, 0-1,200 ft overburden [1] (1)	Method of recovery				
		Surface mining [2]			Underground mining	
		Reserves in the ground [3] (2)	Potentially recoverable [4] (3)	Economically recoverable [5] (4)	Reserves in the ground [3] (5)	Potentially recoverable [6] (6)
Adams	266	163	130		103	51
Billings	2,836	1,078	862		1,758	879
Bowman	1,136	785	628		351	175
Burke	530	117	94		413	207
Burleigh	208	156	125		52	26
Divide	792	137	110		655	328
Dunn	2,992	2,000	1,600		992	496
Golden Valley	1,290	278	222		1,012	506
Grant	670	115	92		555	278
Hettinger	1,847	980	784		867	434
McHenry	40	15	12		25	13
McKenzie	3,211	825	660		2,386	1,193
McLean	1,923	1,009	807		914	457
Mercer	4,754	1,986	1,589		2,768	1,384
Morton	1,968	342	274		1,626	813
Montrail	749	148	118		601	300
Oliver	1,923	629	503		1,294	647
Renville	59	8	6		51	25
Sheridan	---	---	---		---	---
Slope	4,994	2,326	1,861		2,668	1,334
Stark	2,216	1,275	1,020		941	470
Ward	905	501	401		404	202
Williams	2,144	1,130	904		1,014	507
Total	37,453	16,003	12,802	[5] 7,680	21,450	10,725

[1] From col. 1, table 6. About 98 percent of the total lignite in North Dakota is 1,000 feet or less below the surface. Cumulative production and losses to Jan. 1, 1972 is small. Use of figures for original reserves introduces no appreciable error.

[2] From North Dakota Geological Survey, written communication, Sept. 10, 1973. See also U.S. Bur. Mines (1972).

[3] Col. 2 plus col. 5 equals col. 1.

[4] 80% of figures in col. 2.

[5] 60% of total in col. 3; not classified by county.

[6] 50% of figures in col. 5.

Table 8.--Estimated original lignite resources of South Dakota.[1]

[In millions of short tons. Overburden 0-1,000 ft. All figures are for lignite in the ground. Recoverability of tonnage in column 1 is discussed in table 9.]

County	Original reserves in the ground[2] (1)	Inferred resources and resources in beds less than 5 ft thick (2)	Total estimated resources (3)
Corson	40	10	50
Dewey	200	50	250
Harding	700	1,000	1,700
Meade	---	1	1
Perkins	80	100	180
Ziebach	1	5	6
Total	1,021	1,166	2,187

Cumulative production and losses to Jan. 1, 1972 [3].......... 2

Resources remaining in the ground, Jan. 1, 1972............. 2,185

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[1] From Brown (1952), with modifications to accord with new data on stripping coal resources provided by M. J. Tipton(written commun., 1973); see table 9, col. 2.

[2] Measured and indicated resources in thick and intermediate beds. Includes lignite in beds 5 feet or more thick, plus lignite in thinner beds suitable for strip mining.

[3] Assuming past losses in mining equal past production.

Table 9.--Method of recovery of lignite reserves of South Dakota, Jan. 1, 1972

[In millions of short tons]

County	Original reserves in the ground, 0-1,000 ft overburden [1] (1)	Method of recovery				
		Surface mining [2]			Underground mining	
		Reserves in the ground [3] (2)	Potentially recoverable [4] (3)	Economically recoverable [5] (4)	Reserves in the ground [3] (5)	Potentially recoverable [6] (6)
Corson	40	30	24		10	5
Dewey	200	130	104		70	35
Harding	700	227	182		473	237
Meade	---	---	---		---	---
Perkins	80	40	32		40	20
Ziebach	1	1	1		0	0
Total	1,021	428	343	206	593	297

[1] From col. 1, table 8. Cumulative production and losses to Jan. 1, 1972 is small. Use of figures for original reserves introduces no appreciable error.

[2] M. J. Tipton, South Dakota Geological Survey, written communication, 1973.

[3] Col. 2 plus col. 5 equals col. 1.

[4] 80% of figures in col. 2.

[5] 60% of total in col. 3; not classified by county.

[6] 50% of figures in col. 5.

the process it is likely that the tonnage in column 2 and in other columns to the right of column 2 will also be increased.

Method of Recovery of Coal

Although the tonnages of coal recorded in column 1 of tables 2, 4, 6, and 8 are within easy reach by present mining methods, the mining method must be adapted to the thickness and nature of the coal beds, the thickness and composition of the overlying rocks and the scale and duration of the mining operation.

The methods by which the tonnages recorded in column 1 of these tables are likely to be extracted and the technologic and economic feasibility of extraction are shown in tables 3, 5, 7, and 9. It should be noted that table 3 is a continuation of table 2, and, that to provide continuity, column 1 is the same in both tables. This relation is followed in other pairs of tables as shown below:

State	Total resources (Table no.)	Method of recovery (Table no.)
Montana (eastern)	2	3
Wyoming (northeastern)	4	5
North Dakota	6	7
South Dakota	8	9

Surface Mining

As currently estimated, the amount of coal amenable to strip mining in the Northern Great Plains Region totals 68 billion tons. (See table 10.) This figure is about 48 percent of the total estimated stripping coal resources of the United States (fig. 1). Like the total coal resource tonnage, the stripping coal tonnage is concentrated in

Table 10. - Summary by states of the stripping coal resources of the Northern Great Plains

(In millions of short tons)

State	Reserves in the ground[1] (1)	Potentially recoverable[2] (2)	Economically recoverable (3)
Montana (eastern)	31,857	25,520	15,320
Wyoming (northeastern)	19,850	15,880	13,262
North Dakota	16,003	12,802	7,680
South Dakota	428	343	206
Total	68,138	54,545	36,468

[1] Overburden thickness varies with thickness of coal; maximum generally 200 feet for the thickest beds.

[2] From tables 3, 5, 7, and 9.

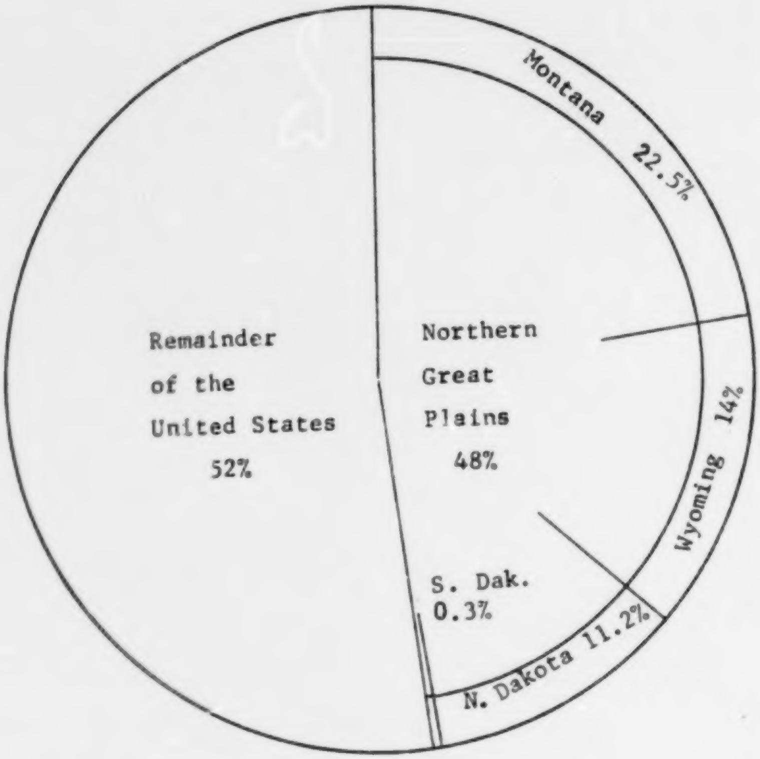

Figure 1.--Percentage distribution of stripping coal resources of the Northern Great Plains region compared to the remainder of the United States.

the compact area of 84,000 square miles, which represents only 18 percent of the total area of coal-bearing rock in the United States.

This pronounced concentration of strippable coal is the result of a combination of several factors: (1) generally flat to gently-dipping coal-bearing rocks; (2) low to gentle topographic relief; and (3) a regional concentration of thick coalbeds.

A breakdown of this huge tonnage of strippable coal by states and by individual counties is presented in tables 3, 5, 7, and 9, and a summary by states is presented in table 10.

The figures in column 2 of tables 3, 5, 7, and 9, which add to the total of 68 billion tons, are for strippable coal in the ground. The amounts that can be recovered by present technology, estimated to be about 80 percent of the coal in the ground, are shown in column 3 of tables 3, 5, 7, and 9. The amounts that are recoverable by current economic standards, about 60 percent of the figures in column 3, are shown in column 4. Coal that is not amenable to strip mining is shown in columns 5 and 6 of tables 3, 5, 7, and 9, and will be discussed under a separate heading below.

Underground Mining

Coal in the choice "reserve" category that can be mined only by underground methods is shown by counties and states in column 5 of tables 3, 5, 7, and 9. The tonnages in column 5 of these tables are based on very conservative assumptions because current interest in coal is centered only on coal in the thicker and more accessible beds.

These tonnages are more than adequate for near-term needs, and large additional tonnages will, of course, become available for future needs through future mapping, exploration, and study.

The figures in column 5 are for coal in the ground. For the United States as a whole, past experience has shown that in underground mining only about 50 percent of the coal in the ground is recovered. This figure does not apply to thick coalbeds. Through use of this factor, the reserves potentially recoverable by underground mining are shown in column 6 of each table.

Only a small amount of coal has been obtained by underground mining in the Northern Great Plains Region in the past, primarily because of the very large amounts of strippable coal that can be mined more efficiently and at a lower cost. It is unlikely, in the opinion of the Mineral Resources Work Group, that any large increase in underground mining will take place in the foreseeable future.

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Coal Chemistry

Complete, detailed knowledge of the composition of coal, organic and inorganic, is basic in any geologic, technologic, and environmental evaluation of this vast resource of fossil fuel in the Northern Great Plains.

Rank and grade are two properties of coal of fundamental importance in considerations of use. Rank is an empirical method of expressing degree of compaction, devolatilization, and biochemical change, which are related primarily to heat and pressure associated with former depth of burial, to time, and to major earth movements.

The coal in the Northern Great Plains Region ranges in rank from lignite B in central North Dakota to subbituminous B on the western edge of the Powder River Basin in northern Wyoming and eastern Montana. (See figure 2.) The east-to-west increase in rank across any one county, for example, is barely perceptible, but the accumulative east-west difference across the 350-mile expanse between central North Dakota and eastern Montana is appreciable.

A small amount of bituminous coal occurs in Crook and Weston Counties, Wyo., on the west flank of the Black Hills uplift, but is considered relatively unimportant for purposes of the present study.

Grade is a means of expressing quality in terms of ash, sulfur, and other deleterious components of the coal, parameters of economic and environmental significance. The amounts of sodium, iron, and calcium can also be of economic concern in coal-combustion processes. The amounts and form of hydrogen in coal can largely determine the feasibility of using a coal for gasification or liquefaction purposes. Though not as well known, the small but measurable amounts of trace elements in coal, such as fluorine, lead, mercury, and selenium, certainly should be precisely known in order to determine possible deleterious effects on the environment during coal use.

The U.S. Bureau of Mines has the responsibility of sampling and analyzing coal purchased by the Federal Government. Data from these analyses are published annually in the Bureau of Mines Report of Investigation series entitled Analyses of Tipple and Delivered Samples of Coal, Collected During Fiscal Year 19__. Individual analyses are reported by state, county, mine, and coalbed. The results of the analyses are also in computer storage in the Bureau's MERIT System (Mines Energy Resources, Information, and Transportation System), and selected analytical parameters by coalbed from MERITS are given in table 11.

The U.S. Geological Survey is active in collecting and analyzing coal samples for trace element content. Data on composition and trace-element content of selected coalbeds are given in tables 12 through 15. The number and type of analyses of each coal sample and the analytical methods used are essentially the same as adopted in the

Table 11. - Average analysis of coal by state, county, bed

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
Montana										
Big Horn										
Dietz No. 1	28.8	3.2	4.6	.2	.4	.4	8,230	11,560	12,120	1
Uncorrelated	23.9	3.4	4.5	.3	.4	.4	9,540	12,540	13,130	18
County total	24.1	3.4	4.5	.3	.4	.4	9,480	12,490	13,080	19
Carter										
Uncorrelated	40.1	10.7	18.0	1.0	1.8	2.1	5,910	9,860	12,030	2
County total	40.1	10.7	18.0	1.0	1.8	2.1	5,910	9,860	12,030	2
Custer										
Moths	34.3	8.4	12.9	.5	.8	.9	6,980	10,620	12,200	1
Johnson Creek	29.1	15.0	21.2	.5	.8	1.0	6,660	9,400	11,920	1
Burley	33.6	9.1	13.8	.5	.8	.9	6,850	10,310	11,960	2
Uncorrelated	29.8	7.1	10.2	.4	.6	.6	7,700	10,960	12,210	13
County total	30.4	7.9	11.4	.4	.6	.6	7,470	10,730	12,110	17
Daniels										
Scobey Bed	41.3	9.2	15.7	.5	.9	1.0	5,680	9,670	11,470	1
Uncorrelated	33.6	8.7	13.2	1.1	1.8	2.0	6,670	10,040	11,570	2
County total	36.2	8.9	14.0	.9	1.5	1.7	6,330	9,920	11,530	3
Dawson										
Carroll	33.0	5.4	8.2	.2	.4	.4	7,400	11,050	12,030	1
Pust	33.7	6.8	10.3	.5	.8	.8	7,090	10,690	11,920	1
Sidney Beds A thru F	31.5	6.3	9.2	.6	.9	.9	6,880	10,040	11,060	1
Uncorrelated	33.6	7.3	11.1	.9	1.4	1.5	7,120	10,720	12,060	13
County total	33.4	7.1	10.7	.7	1.2	1.3	7,120	10,690	11,970	16

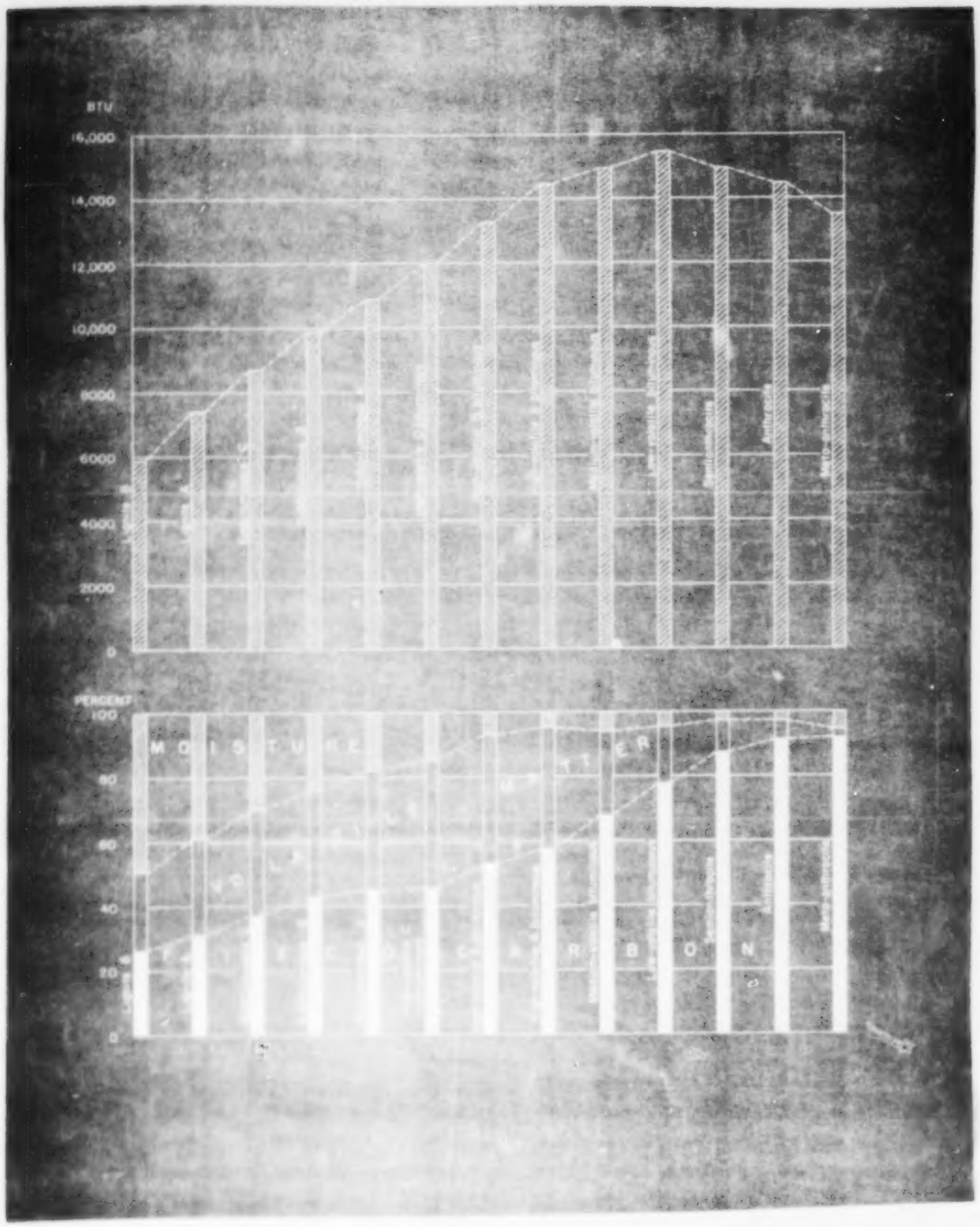

Figure 2. Comparison on a moist, mineral-matter-free basis of heat values and proximate analyses of coals of different ranks.

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Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
Montana--Con.										
Fallon										
Uncorrelated	40.1	10.7	18.0	1.0	1.8	2.1	5,910	9,860	12,030	2
County total	40.1	10.7	18.0	1.0	1.8	2.1	5,910	9,860	12,030	2
Garfield										
Uncorrelated	29.8	12.4	17.8	.4	.6	.7	7,210	10,270	12,490	2
County total	29.8	12.4	17.8	.4	.6	.7	7,210	10,270	12,490	2
McCone										
Tongue River Member Bed R	30.1	7.7	11.1	.5	.8	.8	7,600	10,870	12,230	3
County total	30.1	7.7	11.1	.5	.8	.8	7,600	10,870	12,230	3
Musselshell										
Roundup	11.9	8.8	10.0	.4	.5	.5	10,980	12,460	13,840	428
Uncorrelated	11.1	9.4	10.6	.4	.5	.5	10,870	12,230	13,680	8
Bull Mountain	15.1	8.6	10.2	.8	1.0	1.1	10,500	12,370	13,770	7
Mammoth	15.2	6.9	8.2	.5	.7	.7	10,580	12,480	13,590	24
Carpenter Creek	19.2	7.9	9.8	.8	1.0	1.1	9,680	12,000	13,300	134
County total	13.7	8.5	9.9	.5	.6	.6	10,660	12,350	13,710	601
Powder River										
Pawnee	32.0	5.9	8.8	.2	.3	.3	7,650	11,250	12,330	1
Broadus	29.7	5.8	8.3	.4	.6	.6	7,900	11,240	12,260	14
Flowers Goodale	31.0	7.8	11.4	.4	.7	.7	7,550	10,950	12,350	3
Terrett	30.7	5.8	8.4	.2	.3	.3	7,770	11,220	12,250	3
Sawyer	35.2	4.0	6.2	.3	.5	.5	6,930	10,690	12,400	1
Knoblock	30.1	7.3	10.5	.5	.8	.8	7,800	11,160	12,470	5
Uncorrelated	31.8	6.2	9.2	.2	.3	.3	7,630	11,190	12,320	14
County total	30.8	6.2	9.1	.3	.5	.5	7,730	11,180	12,290	41

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
Montana--Con.										
Prairie										
Uncorrelated	30.6	6.0	8.7	.4	.6	.6	7,840	11,290	12,370	27
County total	30.6	6.0	8.7	.4	.6	.6	7,840	11,290	12,370	27
Richland										
Terrett	27.3	3.9	5.4	.4	.6	.6	9,020	12,410	13,110	.
Brewster	27.3	4.5	6.3	.5	.8	.8	8,850	12,170	12,990	1
Lane	36.5	6.6	10.4	.8	1.4	1.5	7,150	11,260	12,570	1
Lower Elvirio	38.3	5.9	9.7	.4	.8	.8	6,710	10,880	12,040	1
Pust	38.3	5.9	9.7	.4	.8	.8	6,880	11,150	12,350	1
Lee	23.9	7.0	9.3	.6	.8	.8	9,160	12,040	13,270	1
Wright	23.7	11.9	15.7	.6	.8	.9	8,080	10,590	12,560	1
Sawyer	26.6	6.8	9.3	1.8	2.5	2.7	8,080	11,010	12,140	1
Dietz	28.9	3.2	4.6	.2	.4	.4	8,230	11,580	12,130	1
Uncorrelated	35.9	6.0	9.5	.4	.7	.7	7,090	11,060	12,220	48
County total	34.9	6.0	9.3	.5	.8	.8	7,250	11,140	12,280	58
Roosevelt										
Uncorrelated	38.9	6.0	9.9	.6	1.0	1.1	6,170	10,090	11,200	9
County total	38.9	6.0	9.9	.6	1.0	1.1	6,170	10,090	11,200	9
Rosebud										
Uncorrelated	27.7	5.1	7.1	.4	.6	.6	8,710	12,050	12,970	8
Rosebud	23.9	8.1	10.7	.6	.8	.8	8,930	11,730	13,140	8
County total	25.8	6.6	8.9	.5	.7	.7	8,820	11,890	13,050	16
Sheridan										
Uncorrelated	38.0	6.6	10.7	.3	.6	.6	6,350	10,250	11,470	10
County total	38.0	6.6	10.7	.3	.6	.6	6,350	10,250	11,470	10

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
Montana										
Treasure										
Uncorrelated	19.8	14.4	18.0	1.5	1.9	2.3	8,580	10,700	13,050	1
County total	19.8	14.4	18.0	1.5	1.9	2.3	8,580	10,700	13,050	1
Valley										
Scobey Bed C	42.7	8.7	15.2	.5	1.0	1.1	5,640	9,840	11,610	1
Scobey Bed D	37.5	6.1	9.8	.3	.5	.5	6,580	10,530	11,670	1
Uncorrelated	38.9	6.5	10.7	.5	.9	1.0	6,130	10,030	11,230	15
County total	39.0	6.6	10.9	.5	.9	1.0	6,130	10,050	11,270	17
Wibaux										
Sidney Beds A thru F.	39.4	8.7	14.4	.9	1.5	1.7	6,100	10,070	11,760	2
County total	39.4	8.7	14.4	.9	1.5	1.7	6,100	10,070	11,760	2
Yellowstone										
Uncorrelated	20.7	7.7	9.8	.5	.7	.7	8,890	11,210	12,420	19
County total	20.7	7.7	9.8	.5	.7	.7	8,890	11,210	12,420	19
State total	15.6	9.3	11.1	1.0	1.2	1.3	10,010	11,860	13,340	1420
North Dakota										
Adams										
Uncorrelated	33.1	10.5	15.7	1.2	1.8	2.1	7,080	10,590	12,560	34
County total	33.1	10.5	15.7	1.2	1.8	2.1	7,080	10,590	12,560	34
Billings										
Uncorrelated	38.5	6.2	10.1	.8	1.4	1.5	6,350	10,320	11,480	6
County total	38.5	6.2	10.1	.8	1.4	1.5	6,350	10,320	11,480	6

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
North Dakota--Con.										
Bowman										
Uncorrelated	43.4	6.6	11.7	.8	1.5	1.6	6,120	10,810	12,240	8
County total	43.4	6.6	11.7	.8	1.5	1.6	6,120	10,810	12,240	8
Burke										
Uncorrelated	33.4	7.9	11.9	.3	.6	.6	7,260	10,900	12,370	612
County total	33.4	7.9	11.9	.3	.6	.6	7,260	10,900	12,370	612
Burleigh										
Uncorrelated	35.1	6.2	9.7	.6	1.0	1.1	7,100	10,950	12,120	116
County total	35.1	6.2	9.7	.6	1.0	1.1	7,100	10,950	12,120	116
Divide										
Uncorrelated	32.0	7.8	11.6	.4	.7	.7	7,510	11,050	12,500	238
County total	32.0	7.8	11.6	.4	.7	.7	7,510	11,050	12,500	238
Dunn										
Uncorrelated	40.6	7.0	11.9	.6	1.1	1.2	6,310	10,630	12,060	25
County total	40.6	7.0	11.9	.6	1.1	1.2	6,310	10,630	12,060	25
Golden Valley										
Uncorrelated	41.3	5.8	9.9	.6	1.1	1.2	6,330	10,790	11,970	3
County total	41.3	5.8	9.9	.6	1.1	1.2	6,330	10,790	11,970	3
Grant										
Uncorrelated	34.5	10.4	15.9	1.6	2.5	2.9	6,840	10,440	12,410	19
County total	34.5	10.4	15.9	1.6	2.5	2.9	6,840	10,440	12,410	19

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of anal.
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	
North Dakota--Con.										
Hettinger										
Uncorrelated	39.6	8.9	14.9	1.3	2.2	2.5	6,340	10,490	12,330	13
County total	39.6	8.9	14.9	1.3	2.2	2.5	6,340	10,490	12,330	13
McKenzie										
Uncorrelated	42.7	5.0	8.9	.4	.7	.7	6,330	11,040	12,120	5
County total	42.7	5.0	8.9	.4	.7	.7	6,330	11,040	12,120	5
McLean										
Uncorrelated	38.7	6.4	10.5	.4	.8	.8	6,620	10,800	12,070	44
County total	38.7	6.4	10.5	.4	.8	.8	6,620	10,800	12,070	44
Mercer										
Uncorrelated	33.8	6.8	10.4	.5	.9	1.0	7,200	10,880	12,140	728
County total	33.8	6.8	10.4	.5	.9	1.0	7,200	10,880	12,140	728
Morton										
Uncorrelated	39.0	8.0	13.2	1.0	1.7	1.9	6,430	10,540	12,150	38
County total	39.0	8.0	13.2	1.0	1.7	1.9	6,430	10,540	12,150	38
Mountrail										
Uncorrelated	43.1	3.6	6.4	.2	.4	.4	6,440	11,310	12,080	1
County total	43.1	3.6	6.4	.2	.4	.4	6,440	11,310	12,080	1
Oliver										
Uncorrelated	36.5	10.3	16.3	.8	1.4	1.6	6,410	10,100	12,070	20
County total	36.5	10.3	16.3	.8	1.4	1.6	6,410	10,100	12,070	20

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
North Dakota--Con.										
Renville										
Uncorrelated	35.2	6.3	9.8	.9	1.5	1.6	7,090	10,940	12,130	2
County total	35.2	6.3	9.8	.9	1.5	1.6	7,090	10,940	12,130	2
Slope										
Uncorrelated	42.5	6.3	11.0	1.3	2.4	2.6	5,950	10,350	11,630	1
County total	42.5	6.3	11.0	1.3	2.4	2.6	5,950	10,350	11,630	1
Stark										
Uncorrelated	41.1	8.5	14.6	1.1	1.9	2.2	6,150	10,440	12,220	14
County total	41.1	8.5	14.6	1.1	1.9	2.2	6,150	10,440	12,220	14
Ward										
Uncorrelated	37.2	5.5	8.8	.1	.3	.3	6,790	10,820	11,860	899
County total	37.2	5.5	8.8	.1	.3	.3	6,790	10,820	11,860	899
Williams										
Uncorrelated	41.0	6.3	10.8	.5	.9	1.0	6,420	10,880	12,200	38
County total	41.0	6.3	10.8	.5	.9	1.0	6,420	10,880	12,200	38
State total	35.1	6.8	10.5	.4	.7	.7	7,050	10,860	12,130	2864
South Dakota										
Corson										
Uncorrelated	35.9	7.4	11.6	.5	.9	1.0	6,980	10,890	12,320	6
County total	35.9	7.4	11.6	.5	.9	1.0	6,980	10,890	12,320	6

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
South Dakota--Con.										
Dewey										
Firesteel	37.2	6.6	10.6	.4	.7	.7	6,900	11,000	12,300	4
Uncorrelated	35.5	7.4	11.5	.5	.8	.9	7,020	10,890	12,300	18
County total	35.8	7.3	11.4	.5	.8	.9	7,000	10,910	12,310	22
Harding										
Uncorrelated	38.0	10.9	17.6	1.3	2.2	2.6	5,660	9,130	11,080	14
County total	38.0	10.9	17.6	1.3	2.2	2.6	5,660	9,130	11,080	14
Meade										
Uncorrelated			14.2		2.0	2.3		10,560	12,300	1
County total			14.2		2.0	2.3		10,560	12,300	1
Perkins										
Uncorrelated	30.7	12.1	17.6	1.3	2.0	2.4	7,270	10,490	12,720	3
County total	30.7	12.1	17.6	1.3	2.0	2.4	7,270	10,490	12,720	3
State total	36.2	8.8	13.8	.8	1.3	1.5	6,590	10,330	11,980	46
Wyoming										
Campbell										
Smith	33.9	5.0	7.6	.3	.5	.5	7,810	11,820	12,790	4
Felix	31.3	7.0	10.3	1.4	2.1	2.3	7,810	11,370	12,680	4
Ulm No. 2	28.2	8.1	11.3	.9	1.3	1.4	8,050	11,210	12,630	2
Roland	32.3	5.8	8.7	.5	.8	.8	7,930	11,720	12,840	10
Smith-Roland	30.2	6.8	9.8	.5	.8	.8	8,070	11,560	12,810	26
County total	31.0	6.5	9.5	.6	.9	.9	8,000	11,590	12,810	45

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
Wyoming--Con.										
Converse										
Uncorrelated	27.2	5.8	8.1	.3	.5	.5	8,450	11,610	12,630	28
County total	27.2	5.8	8.1	.3	.5	.5	8,450	11,610	12,630	28
Crook										
Uncorrelated	22.2	8.8	11.4	3.5	4.6	5.1	8,930	11,480	12,950	14
County total	22.2	8.8	11.4	3.5	4.6	5.1	8,930	11,480	12,950	14
Johnson										
Healy	28.5	5.7	8.1	.5	.8	.8	7,940	11,110	12,080	7
Uncorrelated	25.8	8.6	11.6	.9	1.3	1.4	8,090	10,900	12,330	10
Upper and Lower Cameron	27.9	9.7	13.5	.5	.8	.9	7,530	10,440	12,070	3
County total	27.0	7.7	10.6	.8	1.1	1.2	7,940	10,880	12,170	20
Natrona										
Uncorrelated	24.5	11.1	14.8	.6	.8	.9	7,850	10,400	12,210	8
County total	24.5	11.1	14.8	.6	.8	.9	7,850	10,400	12,210	8
Niobrara										
Uncorrelated	29.9	7.2	10.4	.7	1.1	1.2	7,660	10,930	12,190	1
County total	29.9	7.2	10.4	.7	1.1	1.2	7,660	10,930	12,190	1
Sheridan										
Various	22.8	4.4	5.8	.3	.5	.5	9,410	12,200	12,940	294
Healy	27.7	7.5	10.4	.4	.6	.6	7,780	10,760	12,010	2
Wall	23.1	4.2	5.5	.4	.6	.6	9,350	12,150	12,860	67
Canyon	24.4	4.7	6.3	.4	.6	.6	9,020	11,930	12,730	8

Table 11. - Average analysis of coal by state, county, and bed--Continued

County - Bed	Moisture	Ash		Sulfur			Btu			No. of
	A.R.1/	A.R.1/	Dry	A.R.1/	Dry	M&AF2/	A.R.1/	Dry	M&AF2/	anal.
Wyoming--Con.										
Sheridan--Con.										
Dietz No. 1	24.7	4.6	6.2	.3	.5	.5	8,900	11,820	12,600	1
Smith	26.3	5.3	7.3	.6	.9	.9	8,340	11,320	12,210	2
Aravada	29.8	5.6	8.0	1.3	1.9	2.0	7,830	11,160	12,130	3
Monarch	21.0	4.5	5.7	.4	.6	.6	9,720	12,310	13,050	1700
Carney	24.9	4.7	6.3	.4	.6	.6	9,020	12,010	12,820	5
Masters	24.5	4.3	5.8	.5	.7	.7	9,220	12,210	12,960	18
Roland	23.5	4.8	6.3	1.3	1.8	1.9	9,010	11,780	12,570	1
Uncorrelated	22.7	5.2	6.8	.3	.5	.5	9,330	12,070	12,950	20
Monarch and Carney	23.6	3.2	4.3	.3	.4	.4	9,520	12,460	13,020	5
County total	21.4	4.4	5.7	.4	.6	.6	9,650	12,280	13,020	2126

1/ As received.
2/ Moisture and ash free.

Table 12.- Quantitative determinations (in ppm) for 12 trace elements in 67 samples of coal from the Powder River Basin of northeastern Wyoming and southeastern Montana. (In thickness column (T) and (B) indicate top and bottom of bed, respectively. Values for Cd, Cu, Li, Pb, and Zn are calculated from analyses of coal.)

Sample No.	Thickness of sample interval (ft)	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se	Th	U	Zn	Ash (percent)
BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING														
D161315	5.(T)	4	<0.1	15.8	---	0.140	10.7	10.0	---	2.3	5.0	2.4	12.6	15.8
D161316	5.5	3	.1	16.9	70	.128	11.6	8.4	0.6	1.6	6.6	2.2	4.0	12.5
SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING														
D161314	6.(T)	2	<0.1	6.2	---	0.088	1.5	5.1	---	0.9	<1.5	0.3	2.6	8.20
D161313	5.	1	<.1	5.7	---	.070	1.0	5.1	---	.7	<1.5	.4	3.4	7.36
D161312	5.	6	.15	18.5	50	.350	4.1	5.9	0.2	3.5	<1.5	<.3	4.1	8.62
D161311	5.	2	<.1	19.0	---	.095	5.8	6.1	---	.6	<1.5	.8	4.5	9.76
D161310	5.(B)	1	<.1	13.4	---	.059	3.5	7.1	---	.8	<1.5	1.1	2.9	10.3
WYODAK-ANDERSON COAL BED, BELLE AYR (AMAX) MINE, GILLETTE, WYOMING														
D160988	(Tipple)	2	0.1	13.3	30	0.13	1.9	5.5	0.2	1.8	<1.5	0.6	6.8	6.64
D163516	2.1(T)	4	.1	12.0	90	.28	1.2	2.2	.4	2.2	<1.5	2.9	6.8	8.69
D163517	4.2	3	.2	45.	80	.13	4.4	5.3	.7	2.0	7.7	1.7	5.9	11.7
D163518	5.	2	.1	8.6	40	.13	2.0	<1.5	.3	.6	4.8	.4	7.6	7.06
D163519	5.	2	<.1	10.7	90	.10	1.2	1.9	.2	.3	<1.5	.4	4.6	6.42
D163520	5.	2	<.1	4.2	65	.08	<.5	<1.5	.2	.4	<1.5	<.3	2.7	4.83
D163521	5.	2	<.1	5.3	60	.06	.5	1.5	.1	.5	<1.5	.6	2.1	4.38
D163522	(Tipple)	2	<.1	12.3	50	.09	1.4	2.2	.2	.9	<1.5	.9	4.4	6.32
WYODAK-ANDERSON COAL BED, WYODAK MINE, GILLETTE, WYOMING														
D160987	(Tipple)	1	<0.1	7.7	30	0.081	1.6	5.6	0.1	0.6	<1.5	0.6	4.2	6.42
D160986	(Shot-pile)	2	.15	22.0	40	.108	4.1	5.7	.3	1.4	<1.5	1.5	12.5	8.82
D160985	3.(T)	2	<.1	3.3	30	.055	.7	3.9	<.1	.4	<1.5	<.2	5.5	4.90
D160984	10.	3	.16	10.0	40	.214	2.2	5.7	.2	1.4	<1.5	.6	7.1	7.94
D160983	10.	2	<.1	20.4	50	.176	4.0	7.1	.3	.8	3.1	.9	15.4	10.6
D160982	10.	1	<.1	8.3	40	.048	2.0	5.7	.1	.6	<1.5	.6	5.6	6.80
D160981	.5	2	<.1	51.	200	.150	49.	<40.	.5	.6	7.9	3.2	25.	84.9
D160980	3.5	1	<.1	9.8	50	.104	4.2	8.1	.3	1.0	<1.5	.5	7.5	9.78
D160979	5.	1	<.1	12.4	40	.068	3.6	8.2	.3	.9	<1.5	.9	8.0	10.0
D160978	5.	1	<.1	7.6	40	.064	1.1	6.2	.3	.4	<1.5	.5	3.3	6.78
D160977	5.	<1	<.1	5.6	30	.063	1.3	7.2	.2	.3	<1.5	.5	4.4	7.34
D160976	5.	<1	<.1	3.8	30	.050	1.9	6.0	.1	1.9	<1.5	.5	3.5	6.20
MONARCH COAL BED, BIG HORN MINE, SHERIDAN, WYOMING														
D161320	(Tipple)	3	0.05	6.4	60	0.090	1.8	2.6	0.2	0.3	<1.5	0.4	9.0	4.74
ANDERSON-DIETZ COAL BED, DECKER MINE, DECKER, MONTANA														
D161317	(Tipple)	3	<0.05	8.6	---	0.103	4.4	2.3	---	0.4	<1.5	0.6	3.8	4.76
D161318	do	4	<.05	8.2	50	.108	4.4	2.4	0.3	.6	<1.5	.6	4.5	4.89
D161319	do	5	<.05	9.2	---	.110	5.3	2.6	---	.9	<1.5	.8	5.8	5.36
ROSEBUD COAL BED, BIG SKY MINE, COLSTRIP, MONTANA														
D163179	6.8(T)	1	<0.1	7.6	105	0.04	12.	6.0	0.3	0.7	<1.5	0.4	1.9	9.17
D163180	5.7	1	<.1	6.2	<20	.03	18.	5.9	.3	.2	<1.5	.6	2.4	9.64
D163181	5.0	1	<.1	6.5	<20	.06	13.	5.0	.2	.2	<1.5	.4	2.6	8.28
D163182	5.0	1	<.1	8.7	40	.08	10.	5.6	.3	.8	<1.5	.5	3.0	13.2
D163183	2.1	1	<.1	3.6	<20	.06	3.7	3.0	.4	.8	<1.5	.5	2.0	5.01
D163192	.3	2	<.1	43.	100	.05	122.	36.	.5	2.4	<1.5	1.5	23.	51.7
D163184	2.5(B)	2	<.1	7.0	20	.16	8.9	6.6	.5	.8	<1.5	.8	3.1	9.11
D163187	(Tipple)	2	.1	7.7	60	.07	14.	7.5	.5	.5	<1.5	.7	5.4	11.5
McKAY COAL BED, BIG SKY MINE, COLSTRIP, MONTANA														
D163186	5.4(T)	1	<0.1	4.6	70	0.05	5.6	5.4	2.7	0.4	<1.5	0.8	2.5	7.18

Table 12.- Quantitative determinations (in ppm) for 12 trace elements in 67 samples of coal from the Powder River Basin of northeastern Wyoming and southeastern Montana--Continued

Sample No.	Thickness of sample interval (ft)	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se	Th	U	Zn	Ash (percent)
ROSEBUD COAL BED, ROSEBUD MINE, COLSTRIP, MONTANA														
D161321	(Shot-pile)	2	<0.1	10.1	60	0.075	14.	7.9	0.7	0.9	5.1	1.2	2.1	13.0
D161322	do.	2	< .1	10.7	---	.053	24.	8.6	---	1.0	4.0	1.3	2.5	13.7
McKAY COAL BED (CORES), ROSEBUD MINE, COLSTRIP, MONTANA														
D161796	?	---	---	---	---	0.144	---	---	---	---	---	---	---	9.73
D161797	?	---	---	---	---	.160	---	---	---	---	---	---	---	9.40
D161798	?	---	---	---	---	.143	---	---	---	---	---	---	---	10.0
D161799	?	---	---	---	---	.148	---	---	---	---	---	---	---	13.1
UNIDENTIFIED COAL BEDS IN 12 CORES, NORTHEASTERN WYOMING AND SOUTHEASTERN MONTANA														
D160662	9(T)	2	---	10.7	80	0.035	0.9	---	43.3	<0.1	<1.5	<0.2	5.9	3.20
D160663	3(B)	2	0.1	26.	70	.082	8.8	18.7	13.7	.4	<1.5	.8	12.2	6.80
D160666	7	2	<.1	13.6	40	.037	1.6	17.7	4.7	< .1	<1.5	.2	5.7	3.25
D160667	1	3	<.1	27.	40	.051	4.2	75.	19.1	<.1	<1.5	.4	8.9	4.56
D160668	11(T)	1	<.1	11.2	70	.044	1.4	13.7	3.8	.2	<1.5	< .2	3.8	4.56
D160669	10	1	<.1	6.2	60	.030	1.0	6.7	1.9	<.1	<1.5	<.2	3.2	3.43
D160670	3(B)	3	.1	10.3	70	.106	3.1	8.5	1.8	.6	<1.5	1.2	17.1	7.12
D160671	4	2	<.1	6.9	70	.035	3.5	6.9	3.0	<.1	<1.5	.9	12.8	6.92
D160672	8(T)	2	.15	10.6	100	.049	3.5	8.6	1.6	.5	<1.5	.8	28.	8.16
D160673	10(B)	2	<.1	5.8	50	.099	1.3	3.9	1.3	.2	<1.5	< .2	5.6	4.87
D161073	10(T)	3	<.1	11.3	---	.043	2.7	11.3	1.3	.6	<1.5	.9	5.8	8.08
D161074	10(B)	4	.1	16.4	---	.065	2.5	30.	1.5	.5	<1.5	.3	7.3	7.30
D161075	1	5	.1	20.	---	.039	1.0	14.1	2.6	.9	<1.5	.5	10.3	6.42
D161076	8(T)	3	<.1	6.6	---	.035	1.6	9.1	1.6	.5	<1.5	.4	2.0	8.24
D161077	10(B)	2	<.1	4.9	---	.021	.6	7.0	.7	.3	<1.5	<.2	1.7	5.40
D161078	7	3	<.1	11.2	---	.058	1.3	7.4	.9	1.0	<1.5	< .2	2.6	6.20
D161079	9(T)	5	.15	20.	---	.181	6.4	9.8	1.4	1.5	5.6	1.7	54.	11.3
D161080	5(B)	3	<.1	6.0	---	.048	1.5	5.7	.6	.5	<1.5	.5	6.9	3.67
D161081	7	4	<.1	5.2	---	.028	.8	5.0	.4	.6	<1.5	.3	5.2	5.00
D161082	10	4	<.1	13.6	---	.041	6.7	11.7	1.2	1.2	4.2	1.5	34.	14.8
D161083	10	3	<.1	5.5	---	.035	1.6	4.5	.2	.3	<1.5	.4	14.6	6.52

Table 13.- Semiquantitative spectrographic analyses (in ppm) for 19 trace elements in 67 samples of coal from the Powder River Basin of northeastern Wyoming and southeastern Montana--Continued

Sample No.	Sample interval (ft)	B	Ba	Be	Co	Cr	Ga	La	Mn	Mo	Nb	Ni	Sc	Sn	Sr	Ti	V	Y	Yb	Zr
ROSEBUD COAL BED, BIG SKY MINE, COLSTRIP, MONT.																				
D163179	6.8(T)	70	700	0.7	<0.5	5	3	7	50	10.	<1.	1.5	1.5	<0.5	300	300	7	3	0.3	30
D163180	5.7	70	150	<.15	<.5	5	3	7	70	2.	2.	1.5	1.5	<.5	200	300	7	3	.3	20
D163181	5.0	50	150	<.15	<.5	5	2	5	20	1.5	<1.	1.	1.	<.5	70	200	5	2	.2	15
D163182	5.0	50	150	<.15	<.5	3	3	<5	30	3.	<1.	1.	1.5	<.5	100	300	7	3	.3	30
D163183	2.1	70	100	.15	.5	1.5	3	5	50	5.	<1.	1.5	1.	<.5	70	150	5	3	.15	10
D163192	.5	30	70	<.15	<.5	15	15	<5	70	5.	<1.	<3.	<3.	<.5	70	3,000	30	10	1.	150
D163184	2.5(B)	70	100	.7	<.5	2	5	7	70	3.	5.	1.5	2.	<.5	100	300	7	5	.3	20
D163187	(Tipple)	50	500	.5	1.	3	3	<5	30	7.	1.5	3.	1.5	<.5	150	300	7	2	.3	20
McKAY COAL BED, BIG SKY MINE, COLSTRIP, MONT.																				
D163186	5.4(T)	70	200	1.	<0.5	2	2	5	15	0.7	1.	2.	1.	<0.5	200	150	5	3	0.3	10
ROSEBUD COAL BED, ROSEBUD MINE, COLSTRIP, MONT.																				
D161321	(Shot-pile)	100	200	0.3	<1.	3	7	<5	100	3.	3.	0.7	1.5	<0.5	200	300	10	3	0.3	30
D161322	do.	100	200	.5	<1.	5	5	<5	100	2.	5.	1.	2.	<.5	300	1,000	10	5	.5	50
McKAY COAL BED (CORES), ROSEBUD MINE, COLSTRIP, MONT.																				
D161796	?	150	30	1.5	2.	2	3	<5	30	5.	2.	5.	1.5	<0.5	200	200	7	5	<0.1	15
D161797	?	150	200	1.5	1.5	3	3	<5	50	1.5	3.	5.	1.5	<.5	200	300	7	5	.5	20
D161798	?	100	700	.7	<1.	3	3	<5	20	1.5	2.	1.	<1.	<.5	300	150	5	3	.3	10
D161799	?	70	50	1.5	<1.	3	3	<5	20	2	<1.5	1.5	<1.	<.5	200	300	10	3	.3	20
UNIDENTIFIED COAL BEDS IN 12 CORES, NE WYO. AND SE MONT.																				
D160662	9(T)	50	500	<0.15	1.	2	1.	<5	15	2.	0.7	1.	1.	1.	200	150	7	1.	0.1	7
D160663	3(B)	20	200	.5	2.	5	2.	5	15	5.	1.5	2.	2.	<.5	200	500	20	3.	.3	10
D160666	7	30	150	<.15	.7	2	1.	<5	15	3.	<.7	.7	1.	.7	500	150	10	1.	.1	5
D160667	1	30	500	<.15	.7	2	1.	<5	20	10.	1.	1.	1.	1.5	300	200	7	1.5	.15	10
D160668	11(T)	30	300	<.15	.7	2	1.	<5	5	2.	1.	.7	.7	<.5	200	200	7	1.5	.15	10
D160669	10	20	300	<.15	.5	1.5	1.	<5	5	1.	<.7	.5	.5	<.5	200	100	5	.7	.07	3
D160670	3(B)	20	500	.2	1.	5	2.	5	7	3.	<.7	5.	1.	<.5	200	200	10	3.	.2	7
D160671	4	100	200	1.	5.	7	2.	5	5	3.	<.7	10.	2.	<.5	20	200	15	5.	.5	10
D160672	8(T)	50	200	.2	1.	5	2.	5	10	1.	1.5	5.	1.	<.5	50	200	15	5.	.5	10
D160673	10(B)	30	200	<.15	.3	1.5	1.	<5	20	.3	<.7	.7	.7	<.5	150	150	7	1.5	.15	5
D161073	10(T)	50	200	<.15	.7	5	1.5	<5	15	1.5	<.7	2.	1.5	<.5	200	200	10	1.5	.15	7
D161074	10(B)	50	200	<.15	1.	3	1.	<5	15	3.	<.7	5.	1.	1.5	200	150	10	2.	.2	5
D161075	1	50	200	2.	3.	3	5.	<5	150	3.	<.7	7.	2.	1.5	300	70	7	10.	.7	3
D161076	8(T)	50	200	<.15	<.3	1.5	1.	<5	50	.7	<.7	.7	<.5	1.5	200	200	5	<.7	<.1	10
D161077	10(B)	50	150	.15	<.3	1	.5	<5	15	.7	<.7	1.	.3	<.5	150	70	3	1.	.1	3
D161078	7	50	300	<.15	1.	3	1.	<5	20	.5	<.7	5.	1.	<.5	200	300	10	2.	.2	10
D161079	9(T)	30	300	.5	3.	10	2.	10	20	.7	<.7	10.	3.	<.5	300	300	30	5.	.5	15
D161080	5(B)	30	300	<.15	1.5	3	1.	5	5	.3	<.7	5.	1.	<.5	300	150	10	3.	.3	5
D161081	7	30	300	<.15	.5	1.5	.7	<5	3	.5	<.7	2.	.7	<.5	300	100	5	1.	.1	5
D161082	10	50	500	.1	5.	15	5.	<5	15	1.	<.7	7.	5.	<.5	700	500	30	5.	.5	15
D161083	10	30	200	<.15	1.	5	1.5	<5	10	<.3	<.7	3.	1.	<.5	700	200	10	1.5	.15	10

Table 13.- Semiquantitative spectrographic analyses (in ppm) for 19 trace elements in 67 samples of coal from the Powder River Basin of northeastern Wyoming and southeastern Montana. (In the sample interval column (T) and (B) indicate top and bottom, respectively. All values have been calculated from analyses on ash of coal.)

Sample No.	Sample interval (ft)	B	Ba	Be	Co	Cr	Ga	La	Mn	Mo	Nb	Ni	Sc	Sn	Sr	Ti	V	Y	Yb	Zr
BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYO.																				
D161315	5.(T)	100	50	0.5	2.	15	7	10	100	2.	3.	5.	5.	<0.5	70	300	50	5	0.5	20
D161316	5.5	100	100	.5	1.	10	7	10	200	2.	2.	7.	2.	< .5	150	500	20	5	.5	10
SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYO.																				
D161314	6.(T)	50	50	0.15	1.	5	1	5	100	0.5	<1.5	3.	1.	<0.5	150	300	10	3	0.15	10
D161313	5.	50	70	<.15	1.	5	1	<5	150	< .5	<1.5	1.5	1.	< .5	150	200	10	2	.2	7
D161312	5.	70	150	.15	1.5	7	3	<5	150	.5	<1.5	7.	1.5	< .5	150	700	15	3	.3	15
D161311	5.	50	200	.3	1.5	7	3	7	70	1.	2.	3.	3.	< .5	300	700	15	3	.3	20
D161310	5.(B)	70	150	.3	1.5	15	7	7	70	1.	3.	3.	3.	< .5	150	700	30	5	.3	15
WYODAK-ANDERSON COAL BED, BELLE AYR (AMAX) MINE, GILLETTE, WYO.																				
D160988	(Tipple)	20	200	0.2	2.	5	2	10	20	0.5	1.5	5.	2.	<0.5	30	300	15	3	0.3	10
D163516	2.1(T)	30	300	.7	3.	7	3	15	200	1.5	2.	10.	5.	< .5	200	300	30	7	.7	15
D163517	4.2	20	300	.7	2.	10	3	20	30	1.	2.	3.	7.	< .5	200	700	30	5	.5	20
D163518	5.	30	200	.3	1.5	5	2	10	20	.5	<1.5	3.	2.	< .5	70	300	10	5	.5	15
D163519	5.	30	200	.2	1.	5	1	5	30	.5	1.5	3.	2.	< .5	70	200	10	2	.3	20
D163520	5.	30	200	<.15	1.	1.5	1	<5	30	.3	<1.5	3.	1.5	< .5	70	150	7	2	.2	7
D163521	5.	30	200	<.15	1.5	3	1	<5	20	.7	<1.5	3.	1.5	< .5	70	150	7	1.5	.15	10
D163522	(Tipple)	20	200	.2	1.	5	1.5	<5	20	.7	1.5	3.	3.	<.5	70	200	10	2	.3	10
WYODAK-ANDERSON COAL BED, WYODAK MINE, GILLETTE, WYO.																				
D160987	(Tipple)	30	200	<0.15	1.	5	2	<5	10	0.5	1.	2.	1.	<0.5	50	200	10	2	0.2	10
D160986	(Shot-pile)	50	200	.3	3.	7	3	<5	200	1.	2.	7.	3.	< .5	50	500	30	5	.7	20
D160985	3.(T)	30	150	< .15	1.5	2	1	<5	50	.3	<1.	3.	.7	< .5	20	100	7	2	.2	5
D160984	10.	50	150	.2	2.	5	2	7	50	.5	1.5	5.	1.	< .5	20	200	15	1	.1	10
D160983	10.	30	200	.3	2.	7	3	10	30	.7	2.	7.	2.	< .5	30	500	20	5	.5	15
D160982	10.	30	200	<.15	1.	5	2	<5	20	.5	<1.	5.	1.	< .5	30	200	10	2	.2	10
D160981	.5	50	500	<.15	< .5	50	20	<5	50	< .5	20.	15.	15.	< .5	150	5,000	150	<1	2.	150
D160980	3.5	20	300	<.15	2.	7	3	<5	15	.7	<1.	3.	1.5	< .5	50	300	15	2	.3	15
D160979	5.	20	200	<.15	1.5	10	3	<5	15	.7	<1.	3.	1.5	< .5	30	300	20	3	.3	15
D160978	5.	20	300	<.15	.7	2	1.5	<5	10	.5	<1.	2.	1.	< .5	50	200	7	2	.2	10
D160977	5.	20	300	<.15	.7	2	2	<5	20	.5	2.	2.	.7	< .5	50	200	5	1.5	.2	10
D160976	5.	30	300	<.15	1.	2	2	<5	10	.7	3.	2.	1.	< .5	70	200	5	2	.2	10
MONARCH COAL BED, BIG HORN MINE, SHERIDAN, WYO.																				
D161320	(Tipple)	30	500	0.15	1.5	3	1.5	3	30	0.5	<1.	5.	1.5	<0.5	100	200	10	3	0.15	10
ANDERSON-DIETZ COAL BED, DECKER MINE, DECKER, MONT.																				
D161317	(Tipple)	30	500	0.15	0.7	3	1.5	3	7	1.5	1.	3.	1.5	<0.5	300	300	10	3	0.15	10
D161318	do.	30	500	.15	1.	3	1.5	3	15	1.5	<1.	3.	1.5	< .5	300	300	15	3	.15	10
D161319	do.	30	500	.15	1.	3	1.5	3	10	1.5	<1.	3.	1.5	< .5	300	300	10	3	.15	10

Table 14.- Proximate, ultimate, Btu, and sulfur analyses of samples of coal from the Powder River Basin of northeastern Wyoming and southeastern Montana. (All analyses, except Btu, in percent; original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination; AR, as received, and MAF, moisture and ash free; (T) and (B) indicate top and bottom of bed, respectively. All analyses of mine samples by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pennsylvania; analyses of drill-core samples by Montana Bureau of Mines and Geology, Butte, Montana.)

Sample No.	USBM Lab. No.	Sample interval (ft)	Moisture	Vol. matter		Fixed C		Ash	Btu		Hydrogen		Carbon		Nitrogen		Oxygen		Sulfur		Sulfate S		Pyritic S		Organic S	
			AR	AR	MAF	AR	MAF	AR	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF
BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING *																										
D161316	K-19970	5.5	15.0	35.4	50.5	34.6	49.5	15.0	8,540	12,200	5.6	5.6	50.9	72.8	0.7	1.0	27.1	19.6	0.7	1.0	0.01	0.01	0.26	0.36	0.44	0.63
SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING																										
D161312	K-19969	5.	14.8	38.6	50.2	38.4	49.8	8.2	9,520	12,370	5.7	5.3	55.8	72.5	0.7	0.9	28.9	20.4	0.7	0.9	0.01	0.01	0.17	0.22	0.55	0.71
WYODAK-ANDERSON COAL BED, BELLE AYR (AMAX) MINE, GILLETTE, WYOMING																										
D160988	K-12883	(Tipple)	26.2	33.6	49.1	34.9	50.9	5.3	8,820	12,880	6.8	5.7	50.7	74.0	0.7	1.1	35.9	18.3	0.6	0.9	0.02	0.04	0.17	0.25	0.44	0.66
WYODAK-ANDERSON COAL BED, WYODAK MINE, GILLETTE, WYOMING																										
D160987	K-12882	(Tipple)	27.1	31.5	46.7	35.9	53.3	5.5	8,530	12,650	6.6	5.3	49.5	73.4	0.7	1.1	37.4	19.7	0.3	0.5	0.01	0.01	0.07	0.11	0.22	0.33
D160983	K-12881	10.	10.4	40.9	50.7	39.7	49.3	9.0	10,280	12,760	5.6	5.6	58.8	73.0	.8	1.0	24.9	19.3	.9	1.1	.09	.11	.09	.11	.70	.87
D160978	K-12880	5.	25.9	32.2	46.9	36.3	53.1	5.6	8,570	12,500	6.4	5.1	50.2	73.2	.7	1.1	36.6	20.1	.5	.5	.08	.11	.09	.14	.20	.30
MONARCH COAL BED, BIG HORN MINE, SHERIDAN, WYOMING																										
D161320	K-19972	(Tipple)	18.7	33.2	43.0	44.0	57.0	4.1	10,080	13,[illegible]30	6.1	5.2	58.4	75.6	1.0	1.3	29.9	17.2	0.5	0.7	0.01	0.01	0.09	0.11	0.45	0.58
ANDERSON-DIETZ COAL BED, DECKER MINE, DECKER, MONTANA																										
D161318	K-19971	(Tipple)	20.6	31.6	42.0	43.4	58.0	4.4	9,88[illegible]	13,160	6.2	5.2	57.1	76.0	0.9	1.2	30.9	17.0	0.5	0.6	0.01	0.01	0.20	0.26	0.26	0.35
ROSEBUD COAL BED, BIG SKY MINE, COLSTRIP, MONTANA																										
D163179	K-24781	6.8(T)	19.8	29.5	40.5	43.3	50.5	7.4	9,550	13,120	5.8	5.0	56.0	76.9	0.9	1.2	29.4	16.2	0.5	0.7	0.01	0.01	0.11	0.15	0.36	0.49
D163180	K-24782	5.7	20.2	31.4	44.0	40.1	56.0	8.3	9,550	13,350	6.1	5.4	55.1	77.0	.8	1.1	29.1	15.7	.6	.8	.00	.00	.26	.36	.30	.42
D163181	K-24783	5.0	20.7	30.9	42.8	41.4	57.2	7.0	9,610	13,290	6.1	5.3	55.2	76.[illegible]	.8	1.1	30.3	16.3	.6	.9	.01	.01	.30	.41	.31	.43
D163182	K-24784	5.0	19.1	29.7	41.3	42.2	58.7	9.0	9,510	13,230	5.7	5.0	54.6	76.0	.8	1.1	29.2	16.9	.7	1.0	.01	.01	.49	.68	.21	.29
D163183	K-24785	2.1	23.0	29.6	40.6	43.1	59.4	4.3	9,650	13,260	6.2	5.0	55.8	76.7	.8	1.1	32.3	16.3	.6	.9	.01	.01	.25	.34	.38	.52
D163184	K-24786	2.5(B)	22.4	29.5	41.9	40.9	58.1	7.2	9,280	13,190	6.2	5.3	53.4	75.8	.8	1.2	31.5	16.4	.9	1.3	.02	.03	.51	.72	.37	.55
D163187	K-24788	(Tipple)	16.4	30.4	41.2	43.5	58.8	9.7	9,720	13,150	5.6	5.1	56.5	76.5	.8	1.1	26.5	16.1	.9	1.2	.01	.01	.56	.76	.29	.39

Table 14.- Proximate, ultimate, Btu, and sulfur analyses of samples of coal from the Powder River Basin of northeastern Wyoming and southeastern Montana--Continued

Sample No.	USBM Lab. No.	Sample interval (ft)	Moisture	Vol. matter		Fixed C		Ash	Btu		Hydrogen		Carbon		Nitrogen		Oxygen		Sulfur		Sulfate S		Pyritic S		Organic S	
			AR	AR	MAF	AR	MAF	AR	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF
McKAY COAL BED, BIG SKY MINE, COLSTRIP, MONTANA																										
D163186	K-24797	5.4(T)	19.7	27.5	37.3	46.3	62.7	6.5	9,380	12,710	5.5	4.5	56.4	76.4	0.8	1.1	30.4	17.5	0.4	0.5	0.01	0.01	0.09	0.12	0.28	0.38
ROSEBUD COAL BED, ROSEBUD MINE, COLSTRIP, MONTANA																										
D161321	K-19973	(Shot-pile)	15.8	30.7	43.1	40.7	56.9	12.8	9,330	13,070	5.5	5.3	54.6	76.5	0.8	1.1	22.8	12.2	3.5	4.9	0.01	0.01	3.23	4.53	0.23	0.33
UNIDENTIFIED COAL BEDS IN 12 CORES, NORTHEASTERN WYOMING AND SOUTHEASTERN MONTANA																										
	MBMG Lab. No.																									
D160662	458	9 (T)	24.8	31.2	42.9	41.6	57.1	2.6	9,560	13,170	NOT DETERMINED								0.3	0.4	0.02	0.02	0.03	0.04	0.25	0.35
D160663	459	3 (B)	25.3	31.1	44.8	38.4	55.2	5.2	9,160	13,160									.7	1.0	.01	.01	.15	.21	.57	.82
D160666	462	7	25.9	31.6	44.4	39.6	55.6	2.9	9,310	13,060									.3	.4	.01	.01	.06	.08	.24	.34
D160667	463	1	21.7	32.6	43.9	[illegible]	56.1	6.1	9,770	13,170									.2	.3	.01	.01	.02	.02	.22	.30
D160668	464	11 (T)	24.1	30.8	42.8	[illegible]	57.2	3.9	9,310	12,910									.2	.3	.02	.02	.04	.06	.19	.27
D160669	465	10	25.2	30.5	42.4	[illegible]	57.6	2.9	9,210	12,810									.2	.3	.02	.02	.03	.04	.18	.25
D160670	466	3 (B)	25.3	29.2	42.4	[illegible]	57.6	6.2	8,710	12,710									.6	.9	.02	.04	.08	.12	.54	.79
D160671	467	4	26.0	30.3	43.2	[illegible]	56.8	7.0	8,440	12,600									.3	.4	.02	.02	.03	.05	.20	.31
D160672	468	8 (T)	25.6	31.9	44.0	36.9	56.0	6.2	8,520	12,460									.6	.9	.02	.04	.09	.13	.48	.70
D160673	469	10 (B)	25.2	31.2	44.1	39.5	55.9	4.1	8,960	12,650									.6	.9	.02	.03	.14	.20	.41	.59
D161073	470	10 (T)	26.1	29.3	43.8	37.6	56.2	7.0	8,400	12,550									.5	.8	.07	.11	.06	.10	.40	.60
D161074	471	10 (B)	23.4	31.6	44.5	39.3	55.5	5.7	9,130	12,880									1.2	1.6	.02	.03	.49	.70	.65	.92
D161075	472	1	31.8	30.7	45.2	36.8	54.8	4.7	7,990	12,580									.6	1.0	.03	.05	.04	.07	.55	.87
D161076	473	8 (T)	31.3	27.0	43.4	35.2	56.6	6.5	7,970	12,810									.7	1.1	.04	.06	.14	.22	.56	.86
D161077	474	10 (B)	31.1	28.1	44.3	35.4	55.7	5.4	8,180	12,870									.7	1.1	.02	.02	.18	.28	.53	.84
D161078	475	7	31.9	29.2	46.3	33.9	53.7	5.0	7,990	12,660									.4	.7	.02	.02	.00	.00	.42	.66
D161079	476	9 (T)	28.2	30.6	51.4	29.0	48.6	12.2	7,950	13,330									.8	1.3	.03	.05	.10	.17	.63	1.05
D161080	477	5 (B)	32.1	26.4	41.4	37.4	58.6	4.1	7,840	12,280									.4	.7	.02	.02	.00	.00	.42	.66
D161081	478	7	34.1	26.4	42.6	35.7	57.4	3.8	7,680	12,320									.2	.3	.01	.02	.00	.00	.16	.25
D161082	479	10	29.1	28.0	47.8	30.7	52.2	12.2	7,130	12,140									.5	.9	.02	.03	.00	.00	.53	.90
D161083	480	10	26.5	30.8	46.7	35.2	53.3	7.5	8,080	12,750									.3	.4	.04	.06	.01	.01	.21	.32

Table 15.- Major-oxide composition (in percent) of the laboratory ash of 63 coal samples from the Powder River Basin, northeastern Wyoming and southeastern Montana. (In sample-interval column (T) and (B) indicate top and bottom, respectively.

Sample No.	Sample interval (ft)	Ash	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SO_3
				BADGER COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING							
D161315	5.(T)	15.8	48.	16.	0.08	0.9	13.	2.00	0.17	3.0	10.
D161316	5.5	12.5	36.	18.	.07	.7	18.	2.30	.91	2.8	12.
				SCHOOL COAL BED, DAVE JOHNSTON MINE, GLENROCK, WYOMING							
D161314	6.(T)	8.20	22.	9.3	0.11	0.2	30.	4.00	0.51	3.8	16.
D161313	5.	7.36	13.	9.6	.12	.2	35.	4.70	.11	3.5	15.
D161312	5.	8.62	22.	12.	.10	.2	27.	3.40	.73	5.4	19.
D161311	5.	9.76	24.	18.	.08	.3	25.	3.10	3.4	2.8	11.
D161310	5.(B)	12.3	32.	16.	.11	.8	22.	2.95	1.5	4.0	9.2
				WYODAK-ANDERSON COAL BED, BELLE AYR (AMAX) MINE, GILLETTE, WYOMING							
D160988	(Tipple)	6.64	26.	13.	1.19	0.3	21.	3.55	0.1	4.6	22.
D163516	2.1(T)	8.69	27.	12.	.98	.4	14.	2.60	1.4	14.	25.
D163517	4.2	11.7	41.	19.	.65	.9	12.	1.80	1.7	2.8	15.
D163518	5.	7.06	31.	16.	1.23	<.1	21.	3.40	.67	3.3	20.
D163519	5.	6.42	31.	9.6	1.28	<.1	24.	3.80	<.05	3.8	17.
D163520	5.	4.83	16.	11.	1.78	.7	29.	4.60	<.05	5.5	22.
D163521	5.	4.38	15.	11.	1.83	.2	29.	4.80	<.05	4.3	25.
D163522	(Tipple)	6.32	25.	12.	1.23	.3	22.	3.60	.40	4.1	23.
				WYODAK-ANDERSON COAL BED, WYODAK MINE, GILLETTE, WYOMING							
D160987	(Tipple)	6.42	30.	13.	1.55	0.5	21.	5.05	1.7	3.3	13.
D160986	(Shot-pile)	8.82	28.	18.	.46	.5	16.	4.15	1.5	2.8	19.
D160985	3.(T)	4.90	17.	12.	.87	.7	24.	6.15	<.05	3.3	21.
D160984	10.	7.54	28.	17.	.60	1.1	16.	4.25	.5	5.2	20.
D160983	10.	10.6	33.	15.	.44	.8	14.	3.25	1.2	4.0	18.
D160982	10.	6.80	21.	13.	1.00	.6	23.	5.80	.7	3.8	21.
D160981	.5	84.9	63.	26.	.13	1.7	.5	.80	.07	1.7	.3
D160980	3.5	9.78	33.	14.	.83	.7	19.	4.90	1.2	3.1	13.
D160979	5.	10.0	41.	15.	.71	1.1	15.	3.80	.6	2.5	10.
D160978	5.	6.78	20.	10.	1.42	.5	27.	8.00	1.1	3.2	15.
D160977	5.	7.34	24.	10.	.98	.7	25.	6.20	.6	4.6	14.
D160976	5.	6.20	26.	11.	1.31	.5	24.	6.85	2.1	3.7	10.
				MONARCH COAL BED, BIG HORN MINE, SHERIDAN, WYOMING							
D161320	(Tipple)	4.74	23.	12.	4.30	0.5	16.	4.60	1.9	9.2	22.
				ANDERSON-DIETZ COAL BED, DECKER MINE, DECKER, MONTANA							
D161317	(Tipple)	4.76	25.	16.	6.90	0.5	14.	2.70	1.1	7.1	20.
D161318	do.	4.89	25.	15.	6.70	.5	14.	2.65	1.2	8.1	20.
D161319	do.	5.36	26.	15.	6.10	.6	13.	2.30	1.3	8.3	21.
				ROSEBUD COAL BED, BIG SKY MINE, COLSTRIP, MONTANA							
D163179	4.8(T)	9.17	48.	16.	0.33	<0.1	9.3	4.60	0.10	1.8	13.
D163180	5.7	9.84	49.	16.	.34	.5	8.8	3.90	.18	2.5	12.
D163181	5.0	8.28	39.	15.	.21	.1	9.7	4.20	.27	5.0	17.
D163182	5.0	10.2	45.	12.	.21	<.1	8.3	3.40	.67	7.7	15.
D163183	2.1	5.01	22.	15.	.42	.1	13.	6.00	.22	5.3	23.
D163192	.5	51.7	37.	13.	.10	<.1	.5	.55	<.05	.2	.5
D163184	2.5(B)	9.11	31.	21.	.22	.1	7.5	3.50	.05	10.	15.
D163187	(Tipple)	11.5	53.	15.	.37	.8	7.6	3.70	.26	5.4	12.
				McKAY COAL BED, BIG SKY MINE, COLSTRIP, MONTANA							
D163186	5.4(T)	7.18	32.	18.	0.38	<0.1	12.	5.35	<0.05	6.7	14.
				ROSEBUD COAL BED, ROSEBUD MINE, COLSTRIP, MONTANA							
D161321	(Shot-pile)	13.0	48.	13.	0.12	<0.1	8.1	3.20	0.26	6.8	13.
D161322	do.	13.7	48.	18.	.13	.3	8.0	3.25	.32	3.9	11.

Table 15.- Major-oxide composition (in percent) of the laboratory ash of 63 coal samples from the Powder River Basin, northeastern Wyoming and southeastern Montana--Continued

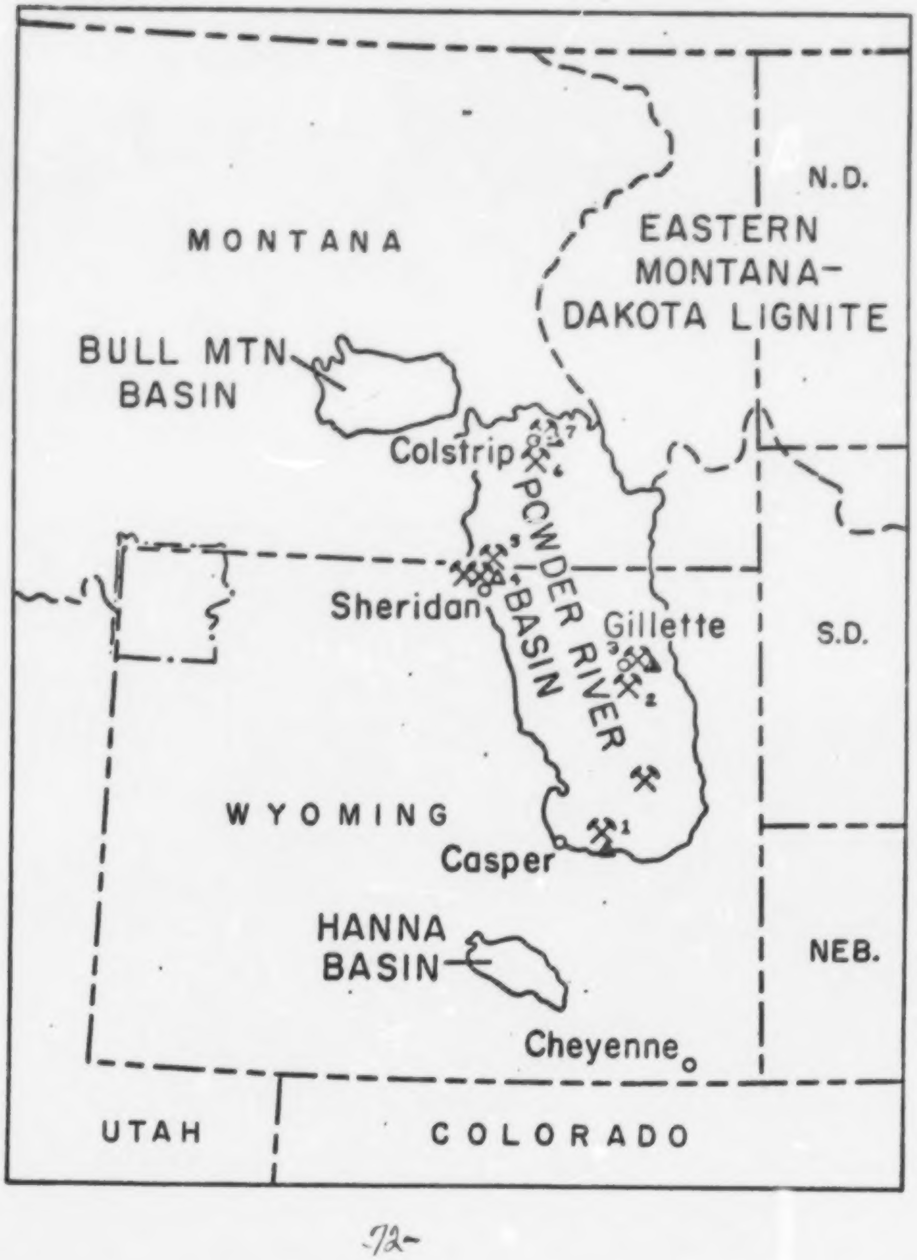
Sample No.	Sample interval (ft)	Ash	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SO_3
UNIDENTIFIED COAL BEDS IN 12 CORES, NORTHEASTERN WYOMING AND SOUTHEASTERN MONTANA											
D160662	9(T)	3.20	31.	15.	2.40	0.4	16.	9.63	1.7	5.8	20.
D160663	3(B)	6.80	35.	22.	1.20	.4	7.9	4.58	1.1	4.7	14.
D160666	7	3.25	16.	13.	2.28	.6	24.	8.75	.23	4.1	20.
D160667	1	4.56	37.	10.	6.10	.3	14.	3.28	.31	4.2	12.
D160668	11(T)	4.56	41.	10.	1.76	.3	18.	9.33	.70	3.9	13.
D160669	10	3.43	14.	14.	1.92	.4	23.	12.3	4.4	5.5	16.
D160670	3(B)	7.12	25.	18.	.94	1.3	11.	5.70	3.8	4.1	16.
D160671	4	6.92	37.	21.	2.72	1.2	8.8	5.43	.86	4.6	7.8
D160672	8(T)	8.16	34.	18.	.19	1.0	12.	3.40	.08	4.1	15.
D160673	10(B)	4.87	18.	10.	.77	.3	18.	8.33	1.5	6.4	22.
D161073	10(T)	8.08	32.	12.	1.40	.4	17.	4.98	1.6	5.6	16.
D161074	10(B)	7.30	27.	11.	2.50	.9	16.	4.02	1.3	7.8	23.
D161075	1	6.42	8.2	7.4	1.85	.2	30.	4.56	.36	8.4	29.
D161076	8(T)	8.24	27.	8.2	.95	4.1	22.	4.23	2.3	4.9	23.
D161077	10(B)	5.40	8.1	4.9	1.50	.1	29.	5.80	4.05	8.6	34.
D161078	7	6.20	25.	9.8	1.80	.1	25.	4.83	.49	4.9	21.
D161079	9(T)	11.3	34.	19.	.93	.6	13.	2.73	1.5	4.8	15.
D161080	5(B)	5.67	15.	13.	2.10	.1	28.	5.58	.45	4.9	21.
D161081	7	5.00	19.	11.	2.25	.4	28.	6.35	3.5	3.7	10.
D161082	10	14.8	42.	23.	.78	1.5	9.3	2.62	.93	4.0	8.6
D161083	10	6.52	40.	14.	.20	1.3	16.	7.13	.61	3.2	9.2

Department of the Interior's Southwest Energy Study (Swanson, 1972; Swanson and Vine, 1972). Analytical values reported herein are on 67 samples of subbituminous coal collected at seven operating coal mines and from 12 drill cores.

Most of the subbituminous coal beds of the Powder River Basin and the lignite beds of the Dakotas and Montana are assigned to the same stratigraphic unit and are of the same age--the Fort Union formation of Paleocene age. The differentiation of the two types of coal (rank) is based on the lower fixed carbon and Btu values of lignite (less than 30 percent and 7,000, respectively), and its characteristically high moisture content (generally more than 30 percent). The geographic dividing line between the two types of coal in the Northern Great Plains area can only be arbitrarily drawn in southeastern Montana, with lignite dominating to the east and northeast and subbituminous coal to the west and south (fig. 3).

Four of the cores of the Powder River Basin coals were drilled in an area 15 to 20 miles north-northwest of Gillette (fig. 3) in Campbell County, Wyo., and eight cores in an area 7 to 20 miles north of Sheridan, Wyo., in Sheridan County, Wyo., and Big Horn County, Mont. Many of the analytical data and the corresponding locality information and driller's logs on the drill cores have been previously presented in an open-filed report by the U.S. Geological Survey and the Montana Bureau of Mines and Geology (1973). The user of chemical information on the drill-core analyses is cautioned on the meaning of some of the trace-element data; some anomalously high values for antimony, lead,

Figure 3. - Location of coal mines in the Powder River Basin from which samples were collected and analyzed. 1, Dave Johnston; 2, Belle Ayr (Amax); 3, Wyodak; 4, Big Horn; 5, Decker; 6, Big Sky; 7, Colstrip. Solid triangles indicate coal-fueled power plants.


N.D.
MONTANA
EASTERN MONTANA-DAKOTA LIGNITE
BULL MTN BASIN
Colstrip
POWDER RIVER BASIN
Sheridan
Gillette
S.D.
WYOMING
Casper
HANNA BASIN
NEB.
Cheyenne
UTAH
COLORADO
1
2
3
4
5
6
7

and zinc, for example, possibly are the result of drill-pipe or drilling fluid contamination.

Additional analyses of trace elements in coal from the Rosebud (Western Energy Company) mine, Colstrip, Mont., have been reported by Chadwick and others (1974). In addition to the analyses reported here, many analyses of lignite can be found in the published literature. The reader is referred to analyses in reports by, particularly, Sondreal, Kube, and Elder, 1968; O'Gorman and Walker, 1972; Zubovic, Stadnichenko, and Sheffey, 1961; Denson and Gill, 1965; Barclay, 1972; and Pipiringos, 1966.

Generalization on average compositions and differences in composition of coal are difficult to make and commonly misleading. The amounts of some chemical components may change by an order of magnitude or more both laterally and vertically within the same coalbed, and certainly from one coalbed to another. Nevertheless, some generalizations are useful in evaluating the coal resources of a region, and, particularly, in judging the quality of coal mined and shipped from a specific mine.

The major differences between the subbituminous coal in the Powder River Basin and the lignite of the Dakotas and eastern Montana are indicated in the following selected average values:

	Subbituminous coal	Lignite
Moisture (as rec'd)	20%	35%
Fixed carbon (as rec'd)	38%	30%
Oxygen (as rec'd)	30%	42%
Btu (as rec'd)	9,000	6,800
SiO_2	25%	15%
Na_2O	0.5%	2%
CaO	15%	25%
MgO	4%	8%
As	2 ppm	5 ppm
B	50 ppm	150 ppm
Ba	200 ppm	700 ppm
Hg	0.08 ppm	0.13 ppm
Pb	6 ppm	3 ppm
U	0.7 ppm	1.1 ppm
Zn	7 ppm	2 ppm

Many other average values are very similar for the subbituminous coal and lignite in the Northern Great Plains. Both are classed as low-sulfur coals, generally containing 0.6 to 0.7 percent S, and their ash contents are generally 5 to 10 percent. Values for many trace elements (in parts per million) are very similar: Be (0.15), Cd (<0.1), F (40), Ni (1.5), Sb (0.3), Sn (<0.5), and Ti (300). Subbituminous coal does contain very slightly larger amounts (in ppm) of a few trace elements compared to lignite: Cr (5 versus 3), Mo (1 versus 0.7), Se (1 versus 0.7), V (10 versus 5), and Zr (15 versus 10).

Some lignite beds in North and South Dakota are locally enriched in uranium, and large tonnages contain 0.1 percent or more uranium (Denson and Gill, 1965; Pipiringos, 1966). These uraniferous lignite beds also generally contain greater amounts of As, Co, Fe, La, Mo, Ni, Pb, Se, and, in some localities, several other elements, but their enrichment is related to secondary mineralization of the lignite. The uranium content of unmineralized lignite is about 0.0001 percent (1 ppm), which is about the same as the average for most coal.

The analytical values reported in tables 16, 17, and 18 are on 62 lignite samples collected from nine operating mines in western North Dakota and one mine in eastern Montana (fig. 4).

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Table 16.-- Quantitative determinations (in ppm) for 12 trace elements in 62 samples of lignite from western North Dakota and eastern Montana. (In thickness column (T), (B), and (M) indicate top, bottom, and middle of bed, respectively. Values for Cd, Cu, Li, Pb, and Zn are calculated from analyses on ash of coal.)

Sample No.	Thickness of sample interval (ft)	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se	Th	U	Zn	Ash (percent)
NOONAN BED, BAUKOL-NOONAN MINE, BURKE COUNTY, NORTH DAKOTA														
D165632	(Tipple)	8	0.1	10.9	70	0.09	3.8	4.3	1.0	0.5	<2.0	1.0	5.8	10.7
COTEAU BED, VELVA MINE, WARD COUNTY, NORTH DAKOTA														
D165605	6.0 (T)	4	<0.1	3.4	40	0.09	1.5	2.1	0.2	0.5	<2.0	1.4	3.2	6.86
D165606	6.0 (M)	5	< .1	4.7	20	.07	2.0	2.0	.2	.4	<2.0	.8	2.3	6.76
D165607	6.0 (B)	10	< .1	8.0	<20	.23	7.0	3.0	.3	1.0	3.3	1.8	2.6	10.0
D165608	6.0 (T)	10	< .1	11.6	35	.17	7.2	4.2	.5	1.3	4.3	2.6	2.5	10.5
D165609	6.0 (M)	5	< .1	3.4	30	.08	1.3	2.0	.1	.3	<2.0	.1	1.8	6.80
D165610	6.0 (B)	4	< .1	3.4	35	.13	1.4	2.2	.1	.3	<2.0	.3	1.8	7.38
D165611	6.0 (T)	4	< .1	4.3	<20	.07	4.2	2.5	.2	.5	<2.0	< .1	2.0	8.34
D165612	6.0 (M)	4	< .1	4.0	20	.10	2.5	2.3	.2	.5	2.8	.5	1.7	7.64
D165613	6.0 (B)	5	< .1	5.7	30	.25	4.3	3.3	.2	.8	3.8	1.3	1.5	8.34
KUTHER (K) AND HAGEL (H) BEDS, GLENHAROLD MINE, MERCER COUNTY, NORTH DAKOTA														
D165564	4.0 (K)	10	<0.1	3.4	<20	0.10	1.	<1.5	0.2	0.7	9.4	2.1	1.4	7.02
D165565	7.0 (H)	5	< .1	6.4	<20	.09	1.2	<1.5	.7	.8	<2.0	1.1	2.2	7.16
D165566	4.0 (K)	15	< .1	3.6	<20	.08	.6	2.0	.4	.8	<2.0	.6	1.3	6.52
D165567	7.0 (H)	5	< .1	2.4	<20	.05	.5	<1.5	3.0	.5	<2.0	.6	2.3	5.78
BEULAH BED, INDIAN HEAD MINE, MERCER COUNTY, NORTH DAKOTA														
D165576	11.0	4	<0.1	7.5	<20	0.05	3.4	4.8	0.3	0.5	3.4	0.9	1.5	9.58
D165577	11.0	10	< .1	10.6	<20	.07	3.8	5.3	1.4	.8	4.0	1.9	9.1	10.6
D165578	11.0	10	< .1	5.6	<20	.34	2.1	3.1	.4	.9	3.2	.7	2.1	10.4
D165579	11.0	15	< .1	5.8	<20	.11	3.3	5.2	.3	1.0	5.0	.9	4.7	10.3
BEULAH BED, SOUTH BEULAH MINE, MERCER COUNTY, NORTH DAKOTA														
D165572	8.0	30	<0.1	4.7	<20	0.21	1.8	7.1	0.5	0.6	<2.0	0.7	27.7	10.2
D165573	3.0	10	< .1	3.2	<20	.19	.7	<1.5	.2	.6	2.5	.4	3.5	6.58
D165574	8.0	5	< .1	7.3	20	.10	7.6	7.6	1.1	1.2	5.5	1.6	5.4	19.1
D165575	3.0	8	< .1	11.3	50	.10	9.9	7.0	1.0	1.5	5.6	2.2	15.0	23.5
HAGEL BED, CENTER (BAUKOL-NOONAN) MINE, OLIVER COUNTY, NORTH DAKOTA														
D165568	10.0	10	<0.1	3.2	20	0.22	0.9	<1.5	0.1	1.0	<2.0	0.5	2.2	10.8
D165569	10.0	8	< .1	6.8	30	.11	1.5	4.7	.5	1.3	3.7	1.5	1.7	9.94
D165570	10.0	5	.1	2.8	<20	.05	.9	1.6	.3	1.6	<2.0	.8	1.6	6.48
D165571	10.0	5	< .1	4.3	<20	.05	.9	2.5	.3	.7	<2.0	.7	1.3	6.28

Table 16.- Quantitative determinations (in ppm) for 12 trace elements in 62 samples of lignite from western North Dakota and eastern Montana--Continued

Sample No.	Thickness of sample interval (ft)	As	Cd	Cu	F	Hg	Li	Pb	Sb	Se	Th	U	Zn	Ash (percent)
HARMON BED, GASCOYNE (PEERLESS) MINE, BOWMAN COUNTY, NORTH DAKOTA														
D165974	4.0 (T, 2nd seam)	1	<0.1	7.5	40	0.08	8.1	6.8	0.2	1.0	---	---	15.8	11.3
D165975	4.0 (1st seam)	2	< .1	4.2	<20	.05	2.5	2.2	.2	.4	---	---	6.1	6.14
D165976	4.0 (1st seam)	4	< .1	3.3	30	.15	<1.	<1.5	.2	.5	---	---	2.1	11.8
D165977	4.0 (1st seam)	4	< .1	2.3	<20	.12	1.	1.8	.2	.4	---	---	1.5	7.30
D165978	4.0 (T, 2nd Seam)	1	< .1	6.7	<20	.16	3.1	3.1	.2	.8	---	---	1.9	7.74
D165979	4.0 (T, 2nd Seam)	5	< .1	8.1	<20	.48	7.5	5.1	.5	1.2	---	---	<1.5	11.3
D165980	4.0 (B, 2nd Seam)	2	< .1	4.2	20	.37	2.1	4.2	.2	.7	---	---	<1.5	10.4
D165981	4.0 (B, 2nd seam)	1	< .1	3.6	<20	.07	2.1	2.7	.1	.2	---	---	<1.5	7.42
D165982	4.0 (1st seam)	10	< .1	2.9	<20	.09	<1.	2.6	.1	.4	---	---	<1.5	6.40
D165983	4.0 (1st seam)	2	< .1	3.7	<20	.06	1.	3.2	.1	.4	---	---	<1.5	8.04
D165984	4.0 (T, 3rd Seam)	2	< .1	4.0	<20	.40	4.5	3.9	.2	.9	---	---	<1.5	8.64
D165985	4.0 (T, 3rd Seam)	2	< .1	4.7	20	.09	3.8	3.3	.5	.6	---	---	<1.5	7.38
D165986	4.0 (B, 3rd seam)	5	< .1	3.3	<20	.42	5.6	4.6	.4	.5	---	---	<1.5	10.3
D165987	4.0 (B, 3rd seam)	1	< .1	15.4	<20	.12	18.7	11.1	.4	1.1	---	---	3.0	11.7
D165988	4.0 (T, 2nd seam)	2	< .1	7.1	70	.31	5.2	<1.5	.2	.8	---	---	<1.5	11.4
D165989	4.0 (T, 2nd seam)	2	< .1	4.4	<20	.60	2.1	<1.5	.4	.9	---	---	<1.5	10.4
D165990	4.0 (B, 2nd seam)	2	< .1	5.0	30	.31	4.6	<1.5	.4	.8	---	---	<1.5	10.0
D165991	4.0 (B, 2nd seam)	2	< .1	6.3	20	.20	4.4	4.1	.4	1.0	---	---	<1.5	8.24
D165992[1]	7.0 (1st seam)	8	< .1	5.1	<20	.13	2.7	3.6	.2	.6	---	---	3.4	12.1
D165993[1]	7.0 (1st seam)	8	< .1	4.1	<20	.11	4.1	<1.5	.2	.5	---	---	<1.5	8.84
PUST BED, SAVAGE MINE, RICHLAND COUNTY, MONTANA														
D165751	14.0 (B, upper seam)	1	<0.1	3.4	55	0.05	2.5	3.2	0.2	0.2	---	---	1.4	6.38
D165752	14.0 (T, upper seam)	2	< .1	4.3	50	.06	2.5	2.8	< .1	.1	---	---	2.2	8.02
D165753	14.0 (B, upper seam)	1	< .1	3.4	60	.04	2.4	2.1	.1	.2	---	---	2.0	7.12
D165754	14.0 (T, upper seam)	2	< .1	3.8	60	.07	1.5	2.4	.2	.3	---	---	1.6	7.92
D165755	14.0 (lower seam)	2	< .1	3.4	90	.15	<1.	<1.5	< .1	.4	---	---	1.0	6.48
D165756	14.0 (lower seam)	1	< .1	3.9	70	.11	.4	1.9	.2	.4	---	---	1.2	6.22
D165757	14.0 (T, upper seam)	2	< .1	5.4	40	.04	10.7	<1.5	.1	.3	---	---	2.3	11.3
D165758	14.0 (B, upper seam)	1	< .1	4.5	40	.06	6.2	3.1	.1	.3	---	---	3.0	8.74
D165759	14.0 (lower seam)	1	< .1	3.6	55	.09	1.1	1.9	< .1	.1	---	---	2.1	6.22
D165760	14.0 (T, upper seam)	2	< .1	9.0	80	.12	4.4	3.5	.5	.6	---	---	1.9	8.64
D165761	14.0 (B, upper seam)	1	< .1	3.9	120	.04	5.1	2.5	.2	.2	---	---	1.4	7.24
D165762	14.0 (lower seam)	1	< .1	2.9	90	.03	.8	1.5	.1	.2	---	---	1.0	5.04
D165763	20.0 (T, upper seam)	3	< .1	6.0	30	.06	16.2	<1.5	.1	.3	---	---	1.7	16.2
D165764	20.0 (T, upper seam)	3	.1	6.1	90	.03	10.0	4.9	.6	.9	---	---	2.2	12.2
D165765	9.0 (T, upper seam)	5	.1	5.6	80	.09	14.3	<1.5	1.6	.4	---	---	16.2	12.1
D165766	9.0 (T, upper seam)	5	.2	9.5	70	.07	22.6	<1.5	1.1	.7	---	---	4.7	15.8

[1] Leonardite (weathered coal, largely soluble in alkaline solution).

Table 17.- Proximate, ultimate, Btu, and sulfur analyses of 35 samples of lignite from western North Dakota and eastern Montana. (All analyses, except Btu in percent; original moisture content may be slightly more than shown because samples were collected and transported in plastic bags to avoid metal contamination; AR, as received, and MAF, moisture and ash free; (T) and (B) indicate top and botoom of bed, respectively. All analyses of mine samples by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pennsylvania.)

Sample No.	USBM Lab. No.	Sample interval (ft)	Moisture	Vol. matter		Fixed C		Ash	Btu		Hydrogen		Carbon		Nitrogen		Oxygen		Sulfur		Sulfate S		Pyritic S		Organic S	
			AR	AR	MAF	AR	MAF	AR	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF
NOONAN COAL BED, BAUKOL-NOONAN MINE, BURKE COUNTY, NORTH DAKOTA																										
165632	K-32669	(Tipple)	24.1	30.8	45.6	36.8	54.4	8.3	8270	12240	6.0	5.0	49.1	72.7	0.9	1.3	35.2	20.3	0.5	0.7	0.0	0.0	0.10	0.15	0.36	0.53
COTEAU BED, VELVA STRIP MINE, WARD COUNTY, NORTH DAKOTA																										
D165608	K-32666	6.0(T)	37.2	27.7	49.0	28.9	51.0	6.2	6720	11870	7.0	5.0	40.1	70.9	0.7	1.2	45.5	22.0	0.5	0.9	0.01	0.01	0.20	0.36	0.27	0.48
D165609	K-32667	6.0	38.9	26.1	45.5	31.2	54.5	3.8	6750	11780	7.0	4.7	40.8	71.2	.6	1.1	47.5	22.6	.3	.4	.01	.01	.01	.01	.24	.42
D165610	K-32668	6.0(B)	37.2	26.3	44.9	32.4	55.1	4.1	6670	11370	6.7	4.4	41.4	70.7	.7	1.1	47.0	23.6	.1	.2	.01	.01	.00	.00	.13	.22
KUTHER (K) and HAGEL (H), GLEN HAROLD MINE, MERCER COUNTY, NORTH DAKOTA																										
D165564	K-31589	4.0(K)	34.6	29.2	47.8	31.9	52.2	4.3	7160	11720	6.8	4.8	42.8	70.0	0.7	1.2	44.9	23.3	0.5	0.7	0.0	0.0	0.02	0.04	0.43	0.70
D165565	K-31590	7.0(H)	28.6	32.7	49.0	34.0	51.0	4.7	7820	11710	6.4	4.8	46.5	69.6	.8	1.2	41.1	23.6	.5	.8	.02	.03	.03	.05	.46	.69
D165566	K-31591	4.0(K)	26.6	32.5	47.4	36.0	52.6	4.9	7980	11640	6.3	4.8	47.7	69.6	.9	1.4	39.6	23.4	.6	.8	.0	.0	.03	.04	.54	.79
D165567	K-31592	7.0(H)	31.4	30.6	47.7	33.6	52.3	4.4	7530	11720	6.7	5.0	44.9	69.9	.8	1.2	42.7	23.2	.5	.7	.0	.0	.03	.05	.42	.65
BEULAH BED, INDIAN HEAD MINE, MERCER COUNTY, NORTH DAKOTA																										
D165576	K-31601	11.0	31.1	26.7	45.4	32.1	54.6	10.1	7010	11900	6.0	4.4	42.6	72.4	0.7	1.2	39.9	20.8	0.7	1.2	0.0	0.0	0.43	0.74	0.26	0.45
D165577	K-31602	11.0	30.1	27.1	47.1	30.5	52.9	12.3	6870	11930	5.9	4.5	40.9	71.1	.7	1.2	37.4	18.4	2.8	4.8	.03	.05	2.39	4.15	.33	.58
D165578	K-31603	11.0	30.7	29.3	46.5	33.8	53.5	6.2	7360	11660	6.2	4.5	44.3	70.2	.7	1.1	42.1	23.4	.5	.8	.01	.01	.14	.22	.34	.53
D165579	K-31604	11.0	31.0	28.3	45.6	33.9	54.4	6.8	7110	11460	6.3	4.5	43.6	70.2	.7	1.2	42.2	23.5	.4	.6	.02	.12	.08	.14	.28	.45
BEAULAH BED, SOUTH BEULAH MINE, MERCER COUNTY, NORTH DAKOTA																										
D165572	K-31597	8.0	29.8	29.1	47.3	32.4	52.7	8.7	7250	11800	6.3	4.8	42.4	69.0	0.5	0.8	39.9	21.8	2.2	3.6	0.05	0.08	1.84	3.00	0.33	0.54
D165573	K-31598	3.0	32.9	28.9	46.6	33.2	53.4	5.0	7430	11960	6.8	5.0	43.9	70.7	.5	.8	43.1	22.4	.7	1.1	.01	.01	.13	.22	.52	.84
D165574	K-31599	8.0	28.4	26.5	47.5	29.2	52.5	15.9	6420	11530	5.6	4.4	40.2	72.2	.7	1.3	36.5	20.1	1.1	2.0	.0	.0	.88	1.59	.22	.39
D165575	K-31600	3.0	30.1	25.1	47.2	28.0	52.8	16.8	6140	11550	5.6	4.3	38.0	71.5	.7	1.3	38.0	21.1	.9	1.8	.01	.01	.74	1.37	.21	.39

Table 17.- Proximate, ultimate, Btu, and sulfur analyses of 35 samples of lignite from western North Dakota and eastern Montana--Continued

Sample No.	USBM Lab. No.	Sample interval (ft)	Moisture	Vol. matter		Fixed C		Ash	Btu		Hydrogen		Carbon		Nitrogen		Oxygen		Sulfur		Sulfate S		Pyritic S		Organic S	
			AR	AR	MAF	AR	MAF	AR	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF	AR	MAF
HAGEL BED, CENTER (BAUKOL-NOONAN)MINE, OLIVER COUNTY, NORTH DAKOTA																										
D165568	K-31593	10.0	34.2	27.3	45.2	33.2	54.8	5.3	7090	11720	6.6	4.6	43.1	71.2	0.7	1.2	43.8	22.2	0.5	0.8	.01	0.01	0.14	0.23	0.31	0.51
D165569	K-31594	10.0	33.8	29.2	50.4	28.7	49.6	8.3	6860	11850	6.7	5.0	40.4	69.7	.7	1.1	42.2	21.2	1.7	3.0	.03	.05	1.26	2.18	.44	.77
D165570	K-31595	10.0	33.2	29.5	47.3	32.9	52.7	4.4	7260	11650	6.6	4.6	43.5	69.8	.7	1.2	44.5	23.8	.3	.6	.02	.03	.04	.07	.29	.46
D165571	K-31596	10.0	34.7	28.9	47.4	32.0	52.6	4.4	7100	11660	6.9	4.9	42.5	69.7	.7	1.2	45.2	23.6	.3	.6	.02	.03	.04	.06	.28	.46
HARMON BED, GASCOYNE (PEERLESS) MINE, BOWMAN COUNTY, NORTH DAKOTA																										
D165976	K-34074	4.0 (1st seam)	46.2	24.9	51.5	23.4	48.5	5.5	5580	11540	7.4	4.6	33.8	69.9	0.4	0.9	52.0	22.8	0.9	1.8	0.03	0.05	0.34	0.70	0.50	1.03
D165979	K-34075	4.0 (T, 2nd seam)	37.5	30.1	55.2	24.3	44.8	8.1	6760	12410	7.2	5.6	39.3	72.2	.6	1.0	43.8	19.4	1.0	1.8	.01	.01	.50	.92	.50	.91
D165980	K-34076	4.0 (B, 2nd seam)	42.2	25.5	49.6	25.9	50.4	6.4	6180	12040	7.3	5.1	36.6	71.4	.4	.9	48.7	21.5	.6	1.1	.06	.11	.06	.11	.46	.90
D165982	K-34077	4.0 (1st seam)	44.6	24.4	47.5	27.0	52.5	4.0	6090	11870	7.5	5.0	36.3	70.7	.5	1.0	51.0	21.9	.7	1.4	.00	.00	.05	.10	.67	1.30
D165985	K-34078	4.0 (T, 3rd seam)	45.0	24.4	48.3	26.2	51.7	4.4	6010	11880	7.5	4.9	35.6	70.5	.5	1.0	51.3	22.1	.7	1.5	.00	.00	.05	.09	.70	1.38
D165986	K-34079	4.0 (B, 3rd seam)	42.3	25.0	49.6	25.6	50.4	7.1	6080	12030	7.3	5.2	35.6	70.5	.4	.9	47.8	19.8	1.8	3.6	.01	.01	.11	.22	1.70	3.37
D165987	K-34085	4.0 (T, 2nd seam)	36.5	27.1	49.1	28.0	50.9	8.4	6550	11900	6.6	4.6	38.6	70.1	.5	.9	43.0	19.0	2.9	5.4	.08	.15	2.26	4.10	.61	1.11
D165990	K-34081	4.0 (B, 2nd seam)	42.7	27.0	52.9	24.1	47.1	6.2	6320	12350	7.5	5.3	36.7	71.7	.5	1.0	48.2	20.2	.9	1.8	.01	.01	.11	.21	.82	1.60
D165992 [1]	K-34082	7.0 (1st seam)	41.5	31.2	63.4	18.1	36.6	9.2	4420	8960	6.4	3.6	29.6	60.1	.7	1.4	52.5	31.6	1.6	3.3	.12	.25	.05	.09	1.48	2.99
D165993 [1]	K-34083	7.0 (1st seam)	38.8	31.5	57.3	23.4	42.7	6.3	5260	9580	6.5	3.9	34.3	62.5	.8	1.4	50.9	30.0	1.2	2.2	.71	1.29	.06	.11	.44	.80
FUST BED, SAVAGE STRIP MINE, RICHLAND COUNTY, MONTANA																										
D165757	K-32673	14.0 (T, upper seam)	34.5	24.6	42.3	33.5	57.7	7.4	6570	11310	6.2	4.0	41.4	71.2	0.7	1.2	44.1	23.2	0.2	0.4	0.00	0.00	0.05	0.09	0.18	0.31
D165758	K-32674	14.0 (B, upper seam)	34.4	28.6	47.3	31.9	52.7	5.1	7070	11680	6.6	4.7	42.5	70.2	.7	1.2	44.9	23.5	.2	.4	.02	.02	.06	.10	.15	.25
D165759	K-32675	14.0 (lower seam)	33.3	29.6	47.7	32.4	52.3	4.6	7450	12000	6.9	5.1	44.1	71.0	.8	1.2	43.2	22.1	.4	.6	.00	.00	.10	.15	.30	.48
D165763	K-32676	20.0 (T, upper seam)	36.4	24.0	44.5	30.0	55.5	9.6	6120	11330	6.6	4.7	38.2	70.7	.7	1.2	44.6	22.9	.3	.5	.00	.00	.07	.12	.20	.37
D166766	K-32677	9.0 (T, upper seam)	38.4	23.7	44.0	30.2	56.0	7.7	6290	11670	6.7	4.5	38.6	71.7	.6	1.2	45.9	21.7	.5	.9	.00	.00	.12	.23	.34	.62

[1] Leonardite (weathered coal, largely soluble in alkaline solution).

Table 18.- Major oxide composition, in percent, of the laboratory ash of 62 samples of lignite from western North Dakota and eastern Montana. (In sample interval column (T), (B), and (M) indicate top, bottom, and middle, respectively.)

Sample No.	Sample Interval (ft)	Ash	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SO_3
NOONAN BED, BAUKOL-NOONAN MINE, BURKE COUNTY, NORTH DAKOTA											
D165632	(Tipple)	10.7	31.	12.	4.13	0.74	15.	3.75	0.03	5.9	15.
COTEAU BED, VELVA STRIP MINE, WARD COUNTY, NORTH DAKOTA											
D165605	6.0 (T)	6.86	6.3	6.0	0.95	<0.10	37.	9.30	<0.05	5.5	12.
D165606	6.0 (M)	6.76	9.2	7.9	.90	< .10	36.	10.7	.15	4.9	13.
D165607	6.0 (B)	10.0	29.	11.	1.30	< .10	23.	6.95	.19	4.0	15.
D165608	6.0 (T)	10.5	27.	12.	1.38	.22	22.	6.85	.26	4.6	17.
D165609	6.0 (M)	6.80	11.	5.7	1.00	< .10	33.	9.75	.24	7.0	17.
D165610	6.0 (B)	7.38	8.	5.8	.93	< .10	38.	9.15	.95	3.8	7.9
D165611	6.0 (T)	8.34	12.	9.2	.78	< .10	35.	8.15	.20	3.7	8.4
D165612	6.0 (M)	7.64	17.	6.6	.85	< .10	30.	9.40	.09	5.1	13.
D165613	6.0 (B)	8.34	17.	9.7	.83	< .10	27.	8.35	.50	4.5	18.
KUTHER (K) AND HAGEL (H) BEDS, GLENHAROLD MINE, MERCER COUNTY, NORTH DAKOTA											
D165564	4.0 (K)	7.02	13.	2.9	8.30	<0.10	26.	5.60	<0.05	4.3	20.
D165565	7.0 (H)	7.16	19.	6.8	9.95	< .10	23.	4.90	.05	5.0	19.
D165566	4.0 (K)	6.52	6.8	4.9	10.4	.20	27.	5.40	< .05	4.4	24.
D165567	10.0 (H)	5.78	12.	4.7	9.20	< .10	28.	4.90	< .05	5.4	23.
BEULAH BED, INDIAN HEAD MINE, MERCER COUNTY, NORTH DAKOTA											
D165576	11.0	9.58	34.	11.	3.50	<0.10	22.	6.00	.97	3.0	12.
D165577	11.0	10.6	26.	11.	3.80	.15	18.	5.25	.26	7.9	22.
D165578	11.0	10.4	16.	8.	3.25	< .10	17.	4.70	.71	15.	30.
D165579	11.0	10.3	27.	11.	3.55	< .10	19.	5.25	.58	7.4	20.
BEULAH BED, SOUTH BEULAH, MERCER COUNTY, NORTH DAKOTA											
D165572	8.0	10.2	20.	9.5	3.95	0.71	12.	4.00	0.06	19.	27.
D165573	3.0	6.58	12.	10.	5.85	.55	21.	6.50	.13	7.7	27.
D165574	8.0	19.1	30.	11.	3.55	.18	21.	3.45	.06	6.5	16.
D165575	3.0	23.5	45.	13.	2.70	.76	9.9	3.05	.07	7.0	14.

Table 18.- Major oxide composition, in percent, of the laboratory ash of 62 samples of lignite from western North Dakota and eastern Montana--Continued

Sample No.	Sample Interval (ft)	Ash	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SO_3
HAGEL BED, CENTER (BAUKOL-NOONAN) MINE, OLIVER COUNTY, NORTH DAKOTA											
D165568	10.0	10.8	12.	3.4	1.15	<0.10	20.	6.00	<0.05	20.	35.
D165569	10.0	9.94	30.	11.	.70	1.2	18.	5.55	< .05	8.6	20.
D165570	10.0	6.48	14.	7.7	1.45	< .10	31.	8.80	< .05	4.0	17.
D165571	10.0	6.28	14.	9.0	1.40	.29	31.	8.65	.06	4.4	17.
HARMON BED, GASCOYNE (PEERLESS) STRIP MINE, BOWMAN COUNTY, NORTH DAKOTA											
D165974	4.0 (T, 2nd seam)	11.3	34.	19.	1.65	<0.10	19.	7.80	<0.05	1.1	14.
D165975	4.0 (1st seam)	6.14	7.3	9.8	.50	< .10	29.	9.10	.06	3.6	35.
D165976	4.0 (1st seam)	11.8	6.1	3.1	.25	< .10	25.	5.90	.07	20.	38.
D165977	4.0 (1st seam)	7.30	4.9	4.8	2.65	< .10	26.	8.40	.10	14.	39.
D165978	4.0 (T, 2nd seam)	7.74	29.	11.	1.05	< .10	23.	8.30	< .05	.89	24.
D165979	4.0 (T, 2nd seam)	11.3	17.	10.	.50	< .10	19.	7.80	< .05	12.	32.
D165980	4.0 (B, 2nd seam)	10.4	11.	6.3	.45	< .10	21.	7.10	.07	15.	37.
D165981	4.0 (B, 2nd seam)	7.42	14.	9.6	.50	< .10	32.	11.1	.06	1.5	26.
D165982	4.0 (1st seam)	6.40	1.0	6.7	1.20	< .10	29.	7.80	< .05	11.	20.
D165983	4.0 (1st seam)	8.04	1.9	4.7	1.55	< .10	30.	9.40	.34	9.5	33.
D165984	4.0 (T, 3rd seam)	8.64	8.5	12.	2.40	< .10	23.	8.00	.33	9.1	22.
D165985	4.0 (T, 3rd seam)	7.38	6.2	18.	2.95	< .10	27.	10.0	.12	2.0	24.
D165986	4.0 (B, 3rd seam)	10.3	8.5	9.4	2.25	< .10	21.	7.30	.05	15.	17.
D165987	4.0 (B, 3rd seam)	11.7	29.	19.	1.65	< .10	21.	6.90	< .05	.12	17.
D165988	4.0 (T, 2nd seam)	11.4	30.	7.7	1.95	< .10	21.	7.10	.36	5.2	34.
D165989	4.0 (T, 2nd seam)	10.4	15.	5.4	2.95	< .10	20.	7.10	.08	18.	27.
D165990	4.0 (B, 2nd seam)	10.0	15.	7.2	2.20	< .10	23.	8.30	.30	9.5	34.
D165991	4.0 (B, 2nd seam)	8.24	6.4	10.	3.90	< .10	29.	10.3	< .05	3.7	36.
D165992 1/	7.0 (1st seam)	12.1	2.8	5.3	2.00	< .10	23.	7.70	.06	14.	45.
D165993 1/	7.0 (1st seam)	8.84	4.5	6.4	2.65	< .10	24.	10.6	< .05	6.8	44.

Table 18.- Major oxide composition, in percent, of the laboratory ash of 62 samples of lignite from western North Dakota and eastern Montana--Continued

Sample No.	Sample Interval (ft)	Ash	SiO_2	Al_2O_3	Na_2O	K_2O	CaO	MgO	P_2O_5	Fe_2O_3	SO_3
PUST BED, SAVAGE MINE, RICHLAND COUNTY, MONTANA											
D165751	14.0 (B, upper seam)	6.38	14.	13.	0.20	< 0.10	31.	11.1	1.1	0.89	12.
D165752	14.0 (T, upper seam)	8.02	11.	12.	.30	< .10	31.	11.6	4.2	1.6	15.
D165753	14.0 (B, upper seam)	7.12	11.	11.	.11	< .10	38.	7.20	1.6	.74	8.3
D165754	14.0 (T, upper seam)	7.92	6.1	11.	.23	< .10	31.	5.80	3.4	8.4	27.
D165755	14.0 (lower seam)	6.48	3.4	11.	.13	< .10	27.	9.30	4.6	9.1	28.
D165756	14.0 (lower seam)	6.22	2.9	16.	.16	< .10	30.	9.40	7.0	5.9	23.
D165757	14.0 (T, upper seam)	11.3	23.	16.	.17	< .10	27.	9.80	< .05	.84	8.9
D165758	14.0 (B, upper seam)	8.74	23.	13.	.38	< .10	25.	10.6	.44	.86	8.7
D165759	14.0 (lower seam)	6.22	8.5	12.	.57	< .10	30.	8.10	2.1	3.4	19.
D165760	14.0 (T, upper seam)	8.64	28.	11.	.35	< .10	23.	9.50	.16	2.1	15.
D165761	14.0 (B, upper seam)	7.24	19.	15.	.44	< .10	28.	12.2	1.3	.48	9.5
D165762	14.0 (lower seam)	5.06	5.9	11.	.65	< .10	33.	14.3	.81	1.4	19.
D165763	20.0 (T, upper seam)	14.2	31.	19.	.16	< .10	23.	6.30	< .05	1.6	7.6
D165764	20.0 (T, upper seam)	12.2	27.	14.	.08	< .10	30.	6.30	< .05	1.4	9.8
D165765	9. (T, upper seam)	12.1	22.	21.	.15	< .10	20.	6.40	1.3	3.0	15.
D165766	9. (T, upper seam)	15.8	28.	20.	.12	< .10	16.	5.00	< .05	2.7	17.

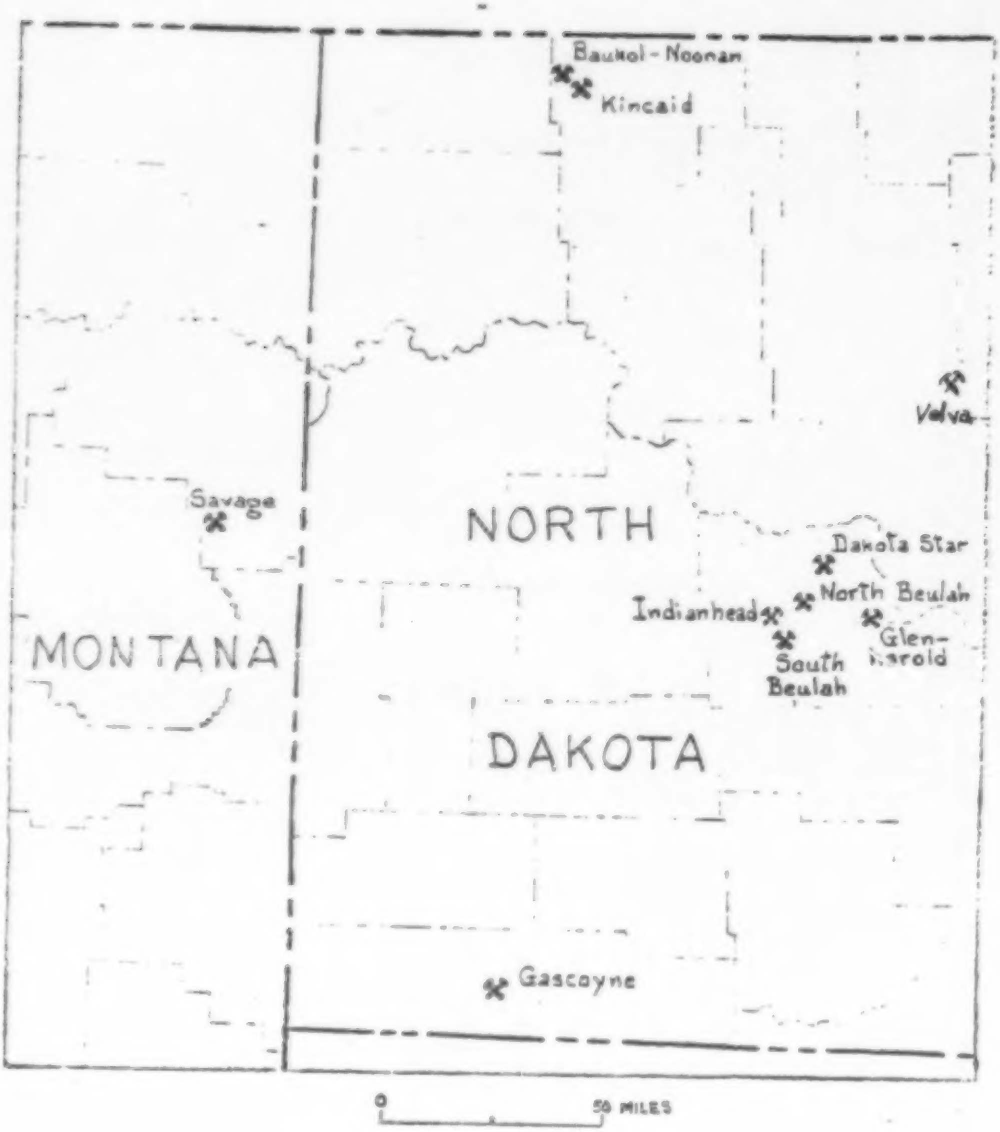
Baukol-Noonan
Kincaid
Velva
Savage
NORTH
Dakota Star
North Beulah
Indianhead
Glen-harold
South Beulah
MONTANA
DAKOTA
Gascoyne
0
50 MILES

Figure 4.--Location of lignite mines in western North Dakota and eastern Montana for which chemical analyses are reported.

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COAL LEGISLATION AND OWNERSHIP

Introduction

The Northern Great Plains became United States territory in 1803 with the Louisiana Purchase. In the middle 1800's, laws were passed dealing with the sale of coal on public domain. Prior to 1900, many thousands of acres of land in the region, including mineral rights, were deeded to various railroads as a form of subsidy during the development of the transcontinental rail system. Originally framed to help finance construction by public sale, much of the railroad land grants remained unsaleable and were retained by the railroads.

In administration of the several homestead acts prior to 1906, coal rights went with the land when it was transferred to private ownership. Between 1906 and 1920, the Federal Government appraised each tract of land for its coal value and fixed the sale price accordingly. During this period, coal rights were sold with some homesteaded tracts and retained by the Federal Government on others. Following passage of the Mineral Leasing Act of 1920, the Federal Government reserved coal rights on all lands classified as valuable for coal when such lands were sold. As a result, the Federal Government is the largest single owner, by a substantial margin, of coal lands and coal rights in the Northern Great Plains Region; the railroad companies are the second largest owners, and the individual states are the third largest owners. However, a substantial amount of coal obtained in the early days of settlement is in private hands.

Following is a discussion of legislation regulating coal leasing from *Preliminary Review Draft Environmental Impact Statement, Proposed Federal Coal Leasing in the United States of America, 1973.*

Coal Deposits - Early Legislation

Coal always has been the subject of special legislation beyond the scope of the general mineral location laws of 1866, 1870, and 1872. Because of its vegetative origin, coal was not classed as a mineral by the Land Department until Congressional legislation declared it to be such.

Before 1864, coal lands were disposed of under settlement and other laws. However, the General Preemption Act passed in 1841 contained a provision that "no lands on which are situated any known salines or mines shall be liable to entry under and by virtue of the provisions of this act." Congress, on July 1, 1864, assuming that coal land had been excluded from the preemption act of 1841, passed legislation providing for the preemption of coal lands in legal subdivisions, at a minimum price of $20 per acre to the highest bidder at public sale. Legislation enacted March 3, 1964, modified the acreage and payment provisions of the 1864 statute to give a preemption right to 160 acres of coal land to a person and 320 acres to an association upon payment of not less than $10 per acre where the lands lay more than 15 miles from a railroad, and $20 per acre where the lands lay within 15 miles thereof. Finally, in 1873, Congress enacted what may be called the "Coal Lands Act," which, with its amendments, governed the disposal of coal deposits on the public domain until the passage of the Mineral Leasing Act of 1920.

The 1873 act reenacted the acreage and payment provision of the Act of March 3, 1865; but added the provision that, when any association of not less than four persons had expended $5,000 in working and improving any mines located within the limits thereby established, they might make an additional entry on 640 acres at the appropriate limit price.

The Coal Lands Act of 1873 was merely an extension of the legislation of 1864 and 1865. Coal quickly acquired value with the extension of the railroads into the West.

One of the chief objects of the Act of 1873, with its restrictions as to the quantity of coal lands which could be acquired by a single purchaser or association of purchasers, was to prevent monopolies in coal lands on the public domain, an object fully respected by the courts.

The Coal Lands Act of 1873 embraced the public lands in the thirteen precious metal-bearing states of the West, together with the public domain in Arkansas, Florida, Louisiana, Mississippi, and parts of Oklahoma. Legislation in 1900 and in 1904 extended the coverage of the act to Alaska, but the act had little or no practical operation there.

The Coal Lands Act of 1873 was further amended in 1909 to permit a person who in good faith had or should locate, select, or enter under the nonmineral land laws of the United States any lands which subsequently should be ascertained to be valuable for coal to elect to receive a patent therefor containing a reservation of the coal to the United States. Such coal deposits would then be subject to disposal by the United States under the coal land laws in force. The following year, Congress provided that unreserved lands of the United States, exclusive of Alaska, already withdrawn or classified as coal lands or valuable for coal, be entered under the homestead laws by actual settlers, or under the desert-land act, with a view of obtaining or passing title, with a reservation to the United States of the coal in such lands. In 1912, Congress provided that unreserved lands of the United States, exclusive of Alaska, withdrawn or classified as coal lands should be subject to selection by the states containing them, under grants made by Congress; the coal deposits, however, being in all such cases reserved to the United States. The same statute gave the Secretary of the Interior discretionary authority to sell, with a reservation of the coal, isolated or disconnected tracts of public lands theretofore withdrawn or classified as coal lands.

Other legislation enacted in 1912 provided: "Unreserved public lands containing coal deposits in the State of Alabama which on April 23, 1912, were being withheld from homestead entry could be entered under the homestead laws of the United States."

Section 1 of the Coal Lands Act of 1873 gave a right of entry by legal subdivisions upon not to exceed 160 acres of vacant coal lands of the United States, not otherwise appropriated or reserved by competent authority. An association of persons could enter upon 320 acres of such lands. The requirement that entry be by legal subdivisions resulted in the construction that the act had no application to unsurveyed coal lands on the public domain.

The Supreme Court of the United States early decided, in Colorado Coal & Iron Co. v. United States, that the Act of 1873 removed from the operation of the General Preemption Act of 1841 and from the later homestead law only those lands upon which were situated "known mines" coal.

In the first decade of this century, the Director of the U.S. Geological Survey classified many thousands of acres of land as being valuable for coal. Those who had previously located, selected, or entered such lands under the nonmineral land laws of the United States were now in the position of having their entries cancelled. This situation was corrected by an act of March 3, 1909, which gave good faith entrymen under the nonmineral land laws the option to receive a patent to their lands which would contain a reservation to the United States of the coal therein contained. In 1910, Congress authorized entry under the homestead laws and the desert-land law and selection under the Carey Act of unreserved public lands of the United States exclusive of Alaska which had been withdrawn or classified as coal lands or were valuable for coal.

Authority to dispose of coal deposits reserved in patents issued under the foregoing legislation actually was not given the Secretary of the Interior until 1917, and then only in accordance with the coal land laws in force at the time of such disposition.

Further legislation in 1912 provided that, subject to reservation of the coal deposits to the United States, unreserved public lands, exclusive of those in Alaska, withdrawn or classified as coal lands might either be (1) selected by the several states under grants theretofore made by Congress of lands within their borders or (2) sold, in the discretion of the Secretary of the Interior, under the laws providing for the sale of isolated or disconnected tracts of public lands.

The Coal Lands Act of 1873 provided two procedures by which coal lands might be acquired. The first was by the application of a duly qualified person or association to the register of the proper land office, and payment for the lands in the sum of $10 per acre if situated more than 15 miles from a railroad or $20 if more closely situated. The maximum acreage permitted to an individual was 160 acres and to a group of individuals 320 acres. An entry under this section has been declared to be a sale, with no elements of preemption. The second procedure was the same as the first, except that a preference right of entry was granted to a person or association of persons who had opened and improved coal mines upon the public lands and were at the time of the application in actual possession; and, if consisting of a group of four or more persons who had expended at least $5,000 in work and improvements, might enter up to 640 acres. The practical differences between the two proceeding sections would appear to be that, under the second procedure, the entrant would have to prove the known character of the land as coal land.

Enactment of the Mineral Leasing Act of 1920 provided for the disposal of coal lands by leasing rather than by entry and sale. The Coal Lands Act of 1873 ceased to control the future disposition of coal lands. This was true both as to coal deposits within unoccupied public lands and as to those deposits reserved to the United States.

Sections 2 through 8 of the Act of February 25, 1920, authorize the Secretary of the Interior to (1) divide coal lands and coal deposits owned by the United States into leasing units and award leases thereon, (2) issue permits to prospect unclaimed and undeveloped areas of coal lands and coal deposits, and (3) issue limited licenses or permits to prospect for, mine and take for use, coal from public lands. Where lands included in a permit, lease, or license have been disposed of with a reservation of coal deposits, a permittee, lessee, or licensee must make full compliance with the law under which such reservation was made. Where any part of the lands embraced in an application for a coal lease, permit, or license is within a withdrawal which does not preclude disposition of the coal deposits, the head of the Government agency having jurisdiction over the lands will be called upon for a report as to whether there is any objection to the granting of a coal lease, permit, or license.

In awarding leases for coal lands improved and occupied or claimed in good faith, prior to February 25, 1920, the Secretary of the Interior is authorized to consider and recognize the equitable rights of such occupants or claimants. The issuance of competitive coal leases and prospecting permits is entirely discretionary with the Secretary of the Interior.

Coal Prospecting Permits

Where prospecting or exploratory work is necessary to determine the existence or workability of coal deposits in an area, the Secretary of the Interior is authorized to issue prospecting permits for a term of two years. The permit entitles the permittee to the exclusive right to prospect for coal on the land described therein. A coal prospecting permit may be extended for a period of two years if the authorized official of the Interior Department finds that the permittee has been unable, with the exercise of reasonable diligence, to determine the existence or workability of coal deposits in the area covered by the permit. Such a coal prospecting permit is a prerequisite to the issuance of a preference right lease.

Limited Coal Licenses

Section 8 of the Mineral Leasing Act of 1920 authorizes the Secretary of the Interior, under such rules and regulations as he may prescribe, to issue limited licenses or permits for a period of two years to individuals or associations of individuals to prospect for, mine, and take for their use, but not for barter or sale, coal in the public lands and this without payment of rent or royalty. Such licenses or permits may also be issued to municipalities to mine and dispose of coal, without profit, to their residents for household use.

Preference Right Lease

A permittee who shows, prior to the expiration of his permit, that the land included in the permit contains coal in commercial quantities is entitled to a preference right lease for all or part of the land; the area to be taken in a reasonably compact form.

Competitive Lease

Section 2 of the Mineral Leasing Act of 1920 authorizes the Secretary of the Interior, upon the petition of any qualified applicant, to divide any of the coal lands or the deposits of coal owned by the United States into leasing tracts of 40 acres each, or multiples thereof, in such form as, in his opinion, will permit the most economical mining of the coal in such tracts, but not to exceed 2,560 acres in any one leasing tract. Thereafter the Secretary, in his discretion, upon the request of any qualified applicant or on his own motion may offer such lands or deposits of coal for lease, awarding such leases by competitive bidding or by such other methods as he may by general regulations adopt. These leasing tracts or units may be established either as a result of an application or when it is deemed advisable by the Interior Department that additional coal units be established.

Modifications and Leasing of Additional Lands or Coal Deposits

Under section 3 of the Act, a lessee may secure a modification of his lease so as to include contiguous coal lands or deposits if the authorized officer determines that such will be to the advantage of the lessee and the United States.

A rental fee of $0.25 per year is required for a coal prospecting permit and the application therefor must be accompanied by a $10 filing fee. Limited coal licenses are issued without payment of any rent or royalty. The Mineral Leasing Act of 1920 does not prescribe any royalty rate to be included in the prospecting permit. Section 7 of the Mineral Leasing Act of 1920 provides that the royalty for the privilege of mining or extracting coal in lands covered by the lease shall be fixed in advance of the lease offer; this same section also prescribes an annual rental payable at the date of such lease and annually thereafter, at such rate as may be fixed by the Secretary of the Interior.

Surface Ownership Map

The Surface Ownership Map (B-1) attempts to depict, in a general way, the surface management responsibilities for various lands in the area. The categories shown include:

1. National Resource Lands--these lands, formerly known as Public Domain, are managed by the Bureau of Land Management (BLM), U.S. Department of the Interior (USDI). Normally, these lands include the mineral rights which are also managed by BLM. District and Resource Area names and boundaries are shown.

2. Acquired Lands--these are former private lands that have been reacquired by the Federal Government. Included here are Land Utilization (L.U.) lands and lands acquired under the Bankhead-Jones Act during the 1930's to remove them from agricultural production. Lands in National Grasslands are managed by the Forest Service, U.S.

Department of Agriculture (USDA). Other acquired lands are managed by BLM. The mineral status for these lands can be quite complex, depending on the terms of the deeds involved. If mineral rights are owned by the Federal Government, they are managed by BLM with the consent of the surface managing agency.

3. Lands managed by Bureau of Sport Fisheries and Wildlife (BSFW), USDI--includes both National Wildlife Refuges and Ranges and small waterfowl areas acquired under the Small Wetlands Acquisition Act in North Dakota. The Charles M. Russell Wildlife Range in Montana is administered jointly by BLM and BSFW. Much of the land managed by BSFW is not available for minerals management.

4. Lands managed by National Park Service (NPS), USDI--these land include National Parks, Monuments, and Recreation Areas. None of the lands managed by NPS in the NGPRP Region are available for minerals management.

5. Bureau of Reclamation, USDI--these lands include withdrawals of Public Domain lands for future water reclamation purposes and active water projects. Depending on the type of withdrawal involved, these lands may or may not be available for minerals management.

6. Bureau of Indian Affairs (BIA), USDI--these lands are Indian lands for which the BIA acts as trustee or advisor to the Indian tribe or individuals involved. As mentioned on note on the map, it is impractical to show the complete status of the lands within the boundaries of the reservations (e.g., trust lands, Indian allotments, private lands, etc.). Mineral rights on Indian lands are managed by the tribes involved.

7. National Forests--these are mostly former Public Domain lands that were made National Forests and are managed by the Forest Service (FS), USDA. Minerals on these lands are managed by BLM with advice of the FS.

8. National Grasslands, Agricultural Research Service--Federal lands within National Grasslands may include both former Public Domain lands (light green) and acquired lands (pink) and are managed by the FS. Minerals, if Federally owned, would be managed by BLM with the advice and consent (acquired lands) of the FS.

9. Corps of Engineers, U.S. Army, Department of Defense--these are generally water projects (e.g., flood control, etc.). These lands are generally not available for minerals management.

10. State Lands--these lands include the so-called school lands (sections 16 and 36 of 640 acres each per township--36 square miles) and other lands acquired by the states involved. Because of the many state agencies which may own lands, and difficulty in getting the information, they may not include all lands owned by the state. In some places the states have sold the surface and retained the mineral rights; these areas are not shown.

11. Private Lands--Non-Federal, non-State, non-Indian lands are shown in white. These lands include the railroad-grant lands (so-called checkerboard lands) and many other possible categories. Mineral rights for these lands may or may not have been reserved to the Federal Government. If reserved, these rights are managed by BLM. Reserved mineral rights are shown on Mineral Management Map (B-2, A, B, C, and D).

Minerals Management Map

The Minerals Management Map attempts to depict, in a general way, the following:

1. Areas where the surface and minerals are both owned by the Federal Government and where the Secretary of the Interior (acting through the BLM) has authority to manage the minerals. The Forest Service manages construction minerals (stone, sand and gravel) in the National Forests. These areas may include lands where the surface is managed by the BLM, Bureau of Sport Fisheries and Wildlife, Bureau of Reclamation of the Department of the Interior, and Forest Service of the Department of Agriculture. Lands known to be closed to minerals management (e.g., most National Parks and Monuments) are not shown. Lands known to be subject to withdrawals preventing minerals management are not shown; however, no attempt has been made to provide complete status.

2. Acquired lands where the surface is Federally owned (management undifferentiated) and all or part of the minerals estate is Federally owned. Acquired Federal minerals are managed by BLM with the consent of the Surface Management Agency.

3. Areas of Reserved Minerals where the surface has been patented (in non-Federal ownership) and which are subject to the same general type of minerals management as above. The categories shown include:

   a. All minerals reserved.

   b. Coal only.

   c. Oil and gas only.

   d. Coal, oil, and gas only.

e. Other mineral reservation situations. This is a "catch-all" category which may include reservations of a large number of minerals individually or in various combinations. It may also include a partial interest in some or all minerals or a future interest in minerals. Coal rights may or may not be included.

4. Because of the interest in potential Federal coal leasing, areas potentially subject to coal leasing have been shown by using various shades of reds and browns for categories 1, 2, and 3 a, b, d, and e above. This does not mean that all of the areas shown in these colors are underlain by coal or that future coal leasing will take place in any or all of these areas. These decisions will be made on the full consideration of all factors under the Secretary of the Interior's coal policy, BLM's planning system including projected energy demands, the results of the Northern Great Plains Resource Program, Energy policies and programs and other factors. Certain of the lands colored in reds and browns were leased several years ago. These areas are shown on plate B-2, A, B, C, D.

5. Uncolored areas are areas where the Federal Government has no minerals management responsiblity. This may include areas where surface is owned by Federal or state governments, Indians or private entities (including railroad lands) and the minerals are non-Federally owned or are otherwise not available for management.

Because of the small scale of the map, it is not possible to show areas below 40 acres in size.

CURRENT COAL MINING TECHNOLOGY IN THE NORTHERN GREAT PLAINS

Introduction

Currently, all of the coal produced in the Northern Great Plains Region is from surface mines. Underground coal mining was once an active industry in the region; however, economics, poor recovery, and health and safety legislation have forced these mines to close. Production data, both actual and planned, for the years 1972, 1975, and 1980 for the surface mines currently in operation and proposed in the region are shown on table 19. Over 98 percent of the coal mined in the last 10 years was for boiler feed in steam-electric generating stations.

Coal Mining and Use

Electric generating stations are designed for a coal with definite physical and chemical characteristics while a gasification complex will tolerate essentially any feedstock after appropriate pretreatment. Coal requirements for electric generation or coal gasification will depend primarily on the quality of the feedstock used, and tonnage requirements for mine mouth or export will be identical for the same end use. Coal requirements for electric generation and gasification were based on the coal heating value (Btu/lb). The coal requirements are shown on figure 5. The requirements for coal gasification also include feedstock for on-site power generation to run the complex. Electric generating station requirements are based on a net heat rate of 9,400 Btu/kwh, a plant availability factor of .80, and use of cooling towers.

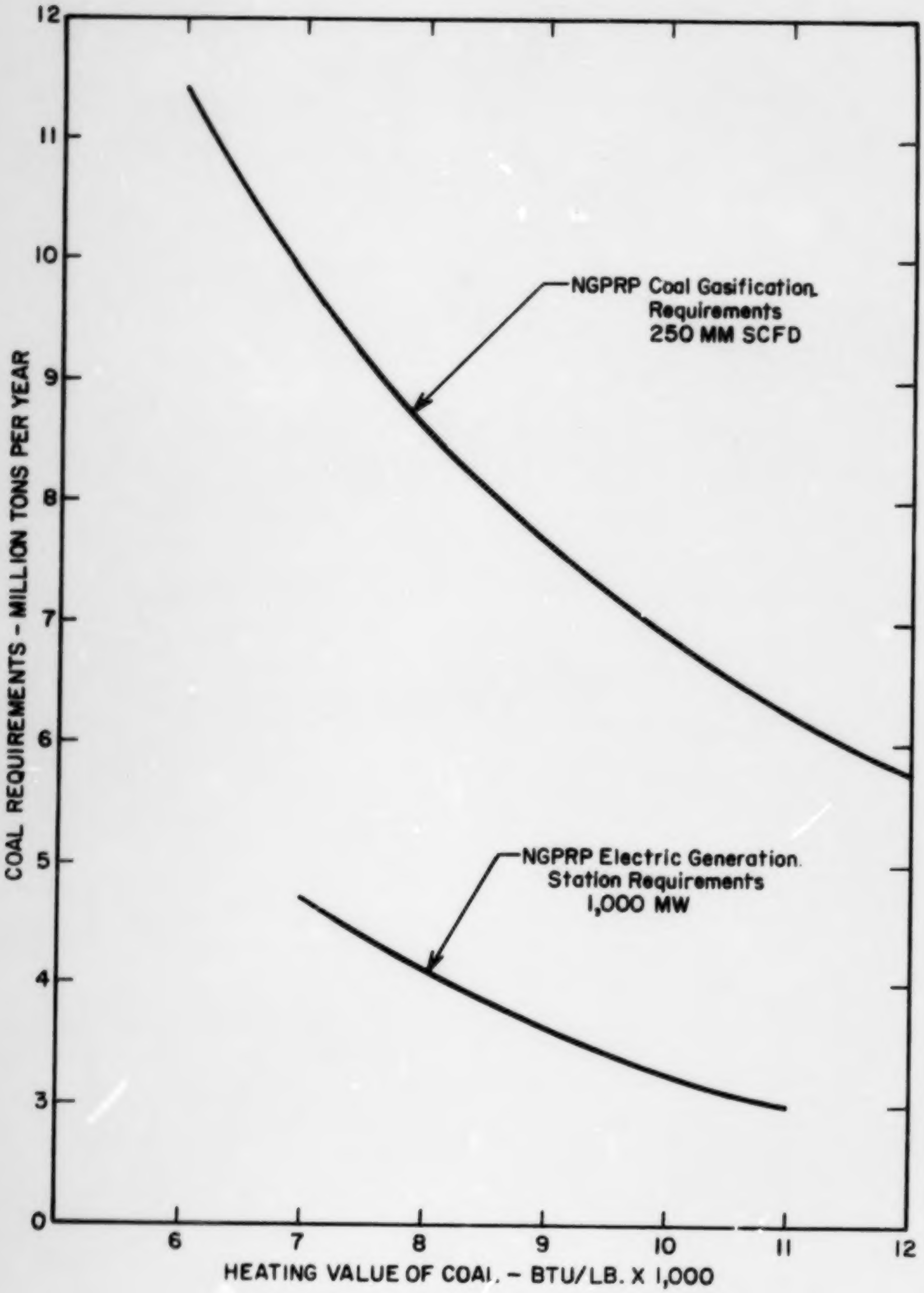

FIGURE 5.- NGPRP Annual Coal Requirements

Table 19. - NGPRP coal production, actual and projected

Mine No.[1]	Company and mine	Type of mine	1972 production[2]	Est. 1975 production[2]	Est. 1980 production[2]
Wyoming					
1	Wyodak Resource Development Co.- Wyodak	Surface	.62	1.0	1.5
2	Amax Coal Co. - Belle Ayr	do.	.03	1.75	9.5
3	Best Coal Co.	do.	.001	.001	.001
4	Pacific Power & Light - Dave Johnson	do.	2.62	2.7	2.8
5	Big Horn Coal Co. - Big Horn	do.	.95	.9	1.0
6	Welch Coal Co.	do.	.02	0.0	0.0
	(Announced or proposed operations)				
7	Carter Oil Co.	do.	--	Doubtful production by 1985	
8	Atlantic Richfield	do.	--	.2	7.0
9	Texaco[3]				
10	Kerr-McGee	do.	--	--	7.0
Montana					
11	Decker Coal Co. - Decker	Surface	.8	6.0	13.0
12	Westmoreland Resources - "Sarpy Creek"	do.	--	4.0	4.0
13	Peabody Coal Co. - Big Sky	do.	1.6	4.0	4.0
14	Western Energy Co. - Colstrip	do.	5.5	5.5	19.32
15	Knife River Coal Co. - Savage	do.	.32	.32	.32
16	Reliable Coal Mining Co.	do.	No report or less than 1,000 tons	Not estimated	
North Dakota					
20	Baukol Noonan Inc. - Baukol Noonan	Surface	1.44	1.5	4.5
21	North American Coal - Indianhead	do.	1.04	1.2	7.2[4]
22	Knife River Coal Mining Co. - Beulah	do.	1.53	1.5	1.5[5]
23	Consolidation Coal Co. - Glenharold	do.	1.42	4.0	4.0[6]

Table 19. - NGPRP coal production, actual and projected--Continued

Mine No.1/	Company and mine	Type of mine	1972 production2/	Est. 1975 production2/	Est. 1980 production2/
North Dakota--Con.					
24	Baukol Noonan Inc. - Noonan Strip	Surface	.48	0.0	0.0
25	Consolidation Coal Co. - Velva	do.	.47	.47	.47
26	Knife River Coal Mining Co. - Gascoyne	do.	.16	3.0	3.0
27	Bonsness Coal Mine - Bonsness	do.	Less than .12 MM tons	Not estimated	
29	Husky Briquetting Inc. - Lenigh Strip	do.	do.	dc.	
30	Arrowhead Coal Co. - Arrowhead Strip	do.	do.	do.	

1/ Refers to mine number on plate B-3.
2/ Production in million tons.
3/ Production plans uncertain.
4/ Possible 10 million tons plus additional production for gasification complex by 1980.
5/ Revised to 5.0 million tons.
6/ Revised to 4.5 million tons.

NOTE. - Mines 17, 18, 19, and 28 are closed. Production data obtained from states and/or companies and reflect fall 1973 production estimates.

Surface Mining Methods

The surface mining of coal may be divided into two distinct types: area and contour. Area mining is restricted to moderately flat to gently rolling terrain as occurs in the Midwest, Northern Great Plains, and New Mexico. Contour mining is restricted to steep hill or ridge sides such as occur in the Appalachian coal fields in the eastern United States.

Three major steps involved in surface mining are overburden removal, coal extraction, and land reclamation. Overburden removal may be accomplished by a number of methods; the method used at any given mine depending on the physical conditions of the coal deposit and associated mining economics. Coal production methods, however, are generally uniform throughout the industry. There is no contour-type surface mining in the study area, at present; the following section will summarize the area-type surface mining methods in the Northern Great Plains Region.

Conventional surface mining, as here defined, uses either electric shovels or draglines for overburden removal. Where required by law, topsoil is first removed by wheel tractor-scrapers and stockpiled for future reclamation. Depending on overburden characteristics, fragmentation of the overburden may be required before the actual stripping operation is initiated. Fragmentation is accomplished by use of an explosive, usually an ammonium nitrate-fuel oil mixture, placed in a series of holes in the area to be stripped. Overburden removal consists of excavating a box-cut or trench to the top of the coal in the vicinity of and parallel to the coalbed-land surface intersection, an area of shallow cover. This cut, depending on the mining plan, may extend for a mile or more to the property limits. Overburden removed from the initial cut is deposited on the pit edge away from the direction of mining.

As overburden stripping continues, a coal loading shovel, often augmented by front-end loaders, will mine the exposed coal, load it into trucks which haul the coal to a plant storage area or a rail loading facility. In many instances, the coal must be broken by explosives or dozer-mounted rippers prior to mining.

After the coal is removed in the initial cut, a second cut is made adjacent to and parallel to the first cut. Overburden excavated from this cut is then placed in the first cut and stripping and mining continue until the economics of overburden removal or physical limits of the stripping equipment are reached.

Generally, reclamation is concurrent with mining. The surface is graded, usually at a speed equal to mining once the mine is in full production, stockpiled topsoil is spread on the leveled surface, and the surface planted. When a mine is supplying coal to a nearby electric generating station, ash from the coal burning process may be hauled back to the mined-out pits for burial before the mined area is reclaimed.

Scraper-dozer mining methods may be used where large areas of thick, near-surface coal occur. Topsoil is first removed and stockpiled, as required, and the overburden is removed by wheeled tractor-scrapers. After coal recovery begins, the overburden is hauled to the mined-out pit, dumped, and pushed into the pit by dozers. A variation of this method employs dozers to strip the upper two-thirds of the overburden and push it into the mined-out area. The remaining overburden is then removed by wheeled-scrapers and spread over the dozed portion of the spoil. A third variation of the above method, which has seen limited use in the study area, consists of moving overburden with wheeled-scrapers and spreading it on land outside of the area to be mined. After coal removal is completed, a nearby stream is diverted into the mined-out pit to create a lake.

One mine in the Northern Great Plains area is presently using a truck-and-shovel method of mining. A 20-cubic-yard electric shovel is used in conjunction with a fleet of 75-ton and 120-ton dump trucks for both overburden removal and coal recovery. In the initial mining operation, overburden was removed from a 40-acre tract and hauled by truck to an area outside of the mine where it was dumped, graded, and seeded. Forty-acre tracts are stripped and mined as a unit. After a unit is stripped, the shovel loads the coal into the same trucks which were used to transport the overburden. After the first unit was mined, the shovel stripped the second unit and the trucks hauled the overburden to the mined-out first unit, which was filled, graded, topsoiled, and planted.

One method of overburden removal, not presently used in the Northern Great Plains, is with a bucket wheel excavator (BWE). The BWE is a stripping machine containing a boom-mounted, bucket-studded wheel and an elevated conveyor system extending to the rear of the excavator. The bucket wheel removes overburden from the working face (highwall) and the conveyor system transports the overburden to the spoil area. Operating costs with the BWE are competitive with conventional stripping equipment, wider pits can be maintained, and spoil piles are more even in size and contour than with other surface mining methods, reducing reclamation costs.

Use of the BWE is limited to poorly consolidated material, free of large rock fragments or boulders. One BWE was used for a short period of time at a coal operation in North Dakota. Small boulders disabled the wheel mechanism. The machine was dismantled and shipped to a more favorable location in the midwestern coal fields.

With sufficient knowledge of overburden lithology and characteristics, the BWE could see limited use in the coal deposits in the Northern Great Plains Region.

Mining Costs

Mining costs, both initial capital investment and annual operating costs (production costs), are extremely difficult to obtain. Mining companies are reluctant to divulge cost data because of the competitive nature of the industry. Also, bookkeeping methods vary between companies, and costs that are charged against mining by one company may be carried differently by a second.

Estimates of mining costs for large-tonnage surface coal mines prepared by personnel of the U.S. Bureau of Mines between 1969 and 1972 are presented in table 20. Detailed information on the two estimates

Table 20. - Summary data on large tonnage hypothetical coal mines

Date of analysis	1969	1969	1972	1972
State	Southwest U.S.	North Dakota	Montana	Wyoming
Coal rank	Subbituminous	Lignite	Subbituminous	Subbituminous
Type operation	Surface	Surface	Surface1/	Surface1/
Coal thickness (feet)	8	10	57	2/
Maximum overburden (feet)	70	50	120	120
Annual tonnage (millions of tons)	5	5	9.20	9.05
Initial capital investment (millions of dollars)	28.66	20.75	22.84	34.12
Deferred capital expenditure (millions of dollars)	----	----	12.92	15.00
Total capital expenditure (millions of dollars)	----	----	35.76	49.12
Production cost (dollars per ton)	2.40	1.68	1.73	2.25
Selling price3/ (dollars per ton)	3.03	2.12	2.02	2.68

1/ Each operation consists of two mines.
2/ Two beds; upper coal thickness 4-85 feet, lower 10-50 feet.
3/ Twelve percent DCF.

dated 1969 may be found in Bureau of Mines Information Circular 8535, "Cost Analyses of Model Mines for Strip Mining of Coal in the United States." The two estimates, dated 1972, for Montana and Wyoming are unpublished.

In comparison with the studies summarized in table 20, the El Paso Natural Gas Co. has estimated that their planned 10.78-million-ton-per-year mine in northwestern New Mexico will cost $113.5 million.

The large differences in initial capital investment among the estimates are due partially to the nature of each estimate. The Bureau of Mines estimates are preliminary analyses, using a minimum of equipment to mine a hypothetical coalbed, while the El Paso estimate is part of a detailed analysis, using known coalbed conditions, to determine the feasibility of producing pipeline-quality gas from coal.

Mine Employment

Mine employment is governed by a number of variables including production requirements, equipment size, geologic conditions, union or non-union contracts, etc. Employment data for existing mines in the Northern Great Plains study area are shown in table 21. Estimated manpower requirements for mines in the production range projected for the Northern Great Plains Region are summarized in figure 6. In comparison, the 10.78-million-ton-per-year mine for the El Paso Natural Gas Co. will employ between 249 and 264 workers.

Reclamation Costs

The cost of reclaiming land per ton of coal produced is difficult to estimate because of the wide range in coal recovery per acre of land surface and variations in costs due to location and proposed land use.

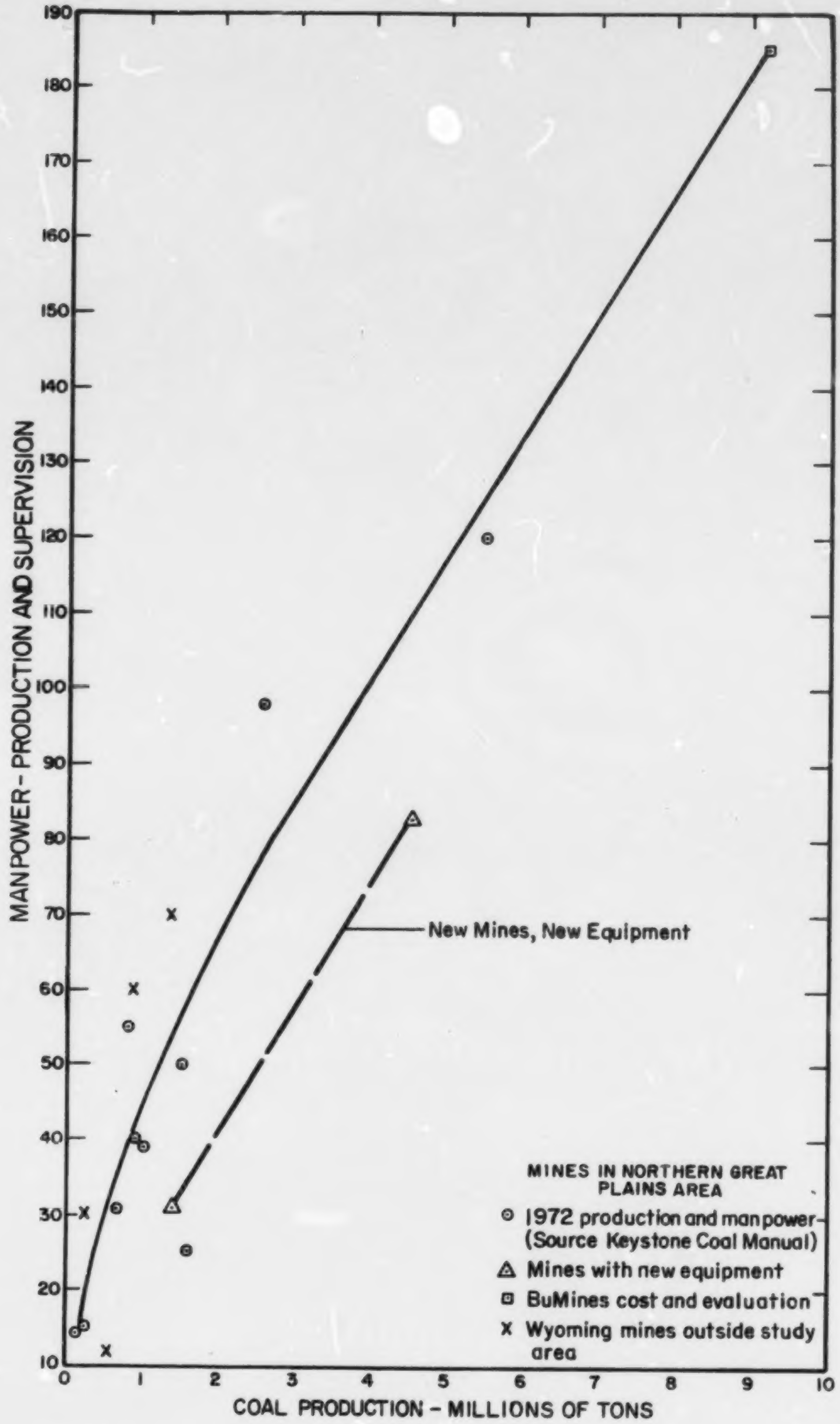

FIGURE 6.- Estimated Manpower Requirements for New Mines by Production Levels

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Table 21. - Surface coal mine production and employment, 1972 Northern Great Plains Resource Program area[1]

Production	Mine employment	Shifts	Plant employment	Shifts	No. seams and coal thickness
Montana					
800,000	55	2	8		1 - 50'
320,975	15	1	3		2 - 20'
1,601,181	25	3	-		2 - 34'
5,500,700	120	3	28	2	1 - 25'
North Dakota[2]					
1,440,620	32[3]	3			
482,928	44	-			
118,065	8				
1,530,000	50	2	16		3 - 27'
165,957	14	1	3		3 - 30'
1,037,236	39	1 to 2			1 - 10'
Wyoming					
955,000	40	2	20	-2	2 - 12' & 42'
2,600,000	98	3			1 - 34'
622,620	31	1			
Wyoming (outside NGPRP area)					
850,000	60	3	40	-3	1 - 76'
259,323	30	1			1 - 60' to 70'
1,843,596	198	1			1 - 50' est.
525,130	12				
1,355,000	70	1	20	1	2 - 12' & 14'

[1] Data from 1973 Keystone Coal Industry Manual.

[2] Does not include mines where employment data are not available.

[3] Company will increase production to 4.5 million tons by 1980 and will hire an additional 53 miners.

One coal company operating in North Dakota uses D-9 dozers in the leveling and grading phase of reclamation. One D-9 dozer, working three shifts, can grade and level one acre of land. The company estimates grading costs at $800 per acre, with soil spreading adding an additional $400 per acre. Seeding costs were estimated at $150 an acre.

Tables 22 and 23, from Extraction of Energy Fuels, a report prepared for the Federal Council for Science and Technology, present comparative reclamation costs in the United States. Table 24 summarizes the range in costs-per-ton in reclaiming surface-mined coal lands in the Northern Great Plains.

Reclamation methods are discussed by the Surface Rehabilitation Potential and Limitations subgroup in the report of the Surface Resources Work Group.

Table 22. - Comparative Reclamation Costs

Operation	Cost
Backfilling and compaction	$.15-.35/cu yd $100-2800/AC*
Strike-off	$25-100/AC
Reclamation	$48-2400/AC
Soil testing	$40/AC
Soil conditioning	$12-13/AC $375/AC
Grass seed	$7-45/AC
Trees, planting cost	$6/AC
Trees, seedlings	$15-40/1000
Sowing seed	$15-20/AC
Planting tree seedlings	$50/AC

*AC - Acre

Table 23. - Basic Reclamation Costs[1/]

Treatment	Per acre cost
Planting	$ 307
Grading	201
Drainage control	259
Diversion ditches	1,100
Slide damage repair	1,322
Haul road repair	496
Stream channel repair	395
Pond stabilization	23
Highwall access	1,618
Hazardous conditions	134
Administration, engineering, and planning at 15%	

[1/] From Surface Mining and Our Environment, U.S. Department of the Interior, 1967 updated to 1971 costs. These costs allow for only a minimum level of reclamation, in which slope angles are reduced, drainage is improved, and a cover crop of some sort is planted. Regrading to restore the original contour of the land or to restore a natural-appearing contour would require costs ranging from $100 to $2,700 per acre.

Table 24. - Range in Costs of Reclaiming Strip-mined Lands in the Northern Great Plains. (In cents per ton of coal recovered.)

Thickness of coal (feet)	Estimated recovery per acre[1/] (tons)	Estimated costs of reclamation per acre (dollars)			
		$500	$1,000	$1,500	$2,000
5	7,100	$0.07	$0.14	$0.21	$0.28
10	14,200	.035	.07	.11	.14
15	21,300	.025	.05	.07	.095
20	28,400	.018	.035	.05	.07
25	35,400	.014	.028	.042	.056
50	70,800	.007	.014	.021	.028
100	141,600	.0035	.007	.01	.014

[1/] Assuming S.G. of coal to be 1.3 and recovery to be 80%.

POTENTIAL METHODS OF COAL RECOVERY

Historically, underground coal production in the United States has predominated in the eastern and midwestern coal fields. The coalbeds in these regions are usually less than 6 feet thick and are capped by a relatively strong roof. Technology for underground mining in this country has developed for these bed conditions, and little research has been directed at recovering the thicker, subsurface beds or the 10- to 20-foot beds under shallow cover in the western United States.

However, in other countries where coalbed thicknesses approach those in the Northern Great Plains Region, the technology has been developed for thick-bed underground coal recovery. The following section will describe potential underground coal recovery methods that may have application in the Northern Great Plains.

Longwall mining is the primary method for which modifications have been made or proposed to extract the thick coalbeds in the Western United States. The longwall method was developed in Europe and is presently being used to mine coal at depths to 4,000 feet. A number of underground coal operations in the eastern part of this country use the longwall system in coalbeds ranging in thickness from four to eight feet.

In conventional longwall mining, blocks of coal up to 600 feet wide and 3,500 feet long are isolated by conventional mining methods, leaving coal pillars to support the entries separating the blocks. Mining then commences on the end of a block and the block is mined with up to 85 or 90 percent coal recovery. Mining equipment consists of a number of self-advancing hydraulic roof supports, which provide a steel canopy over the miners, a coal conveying system, and a mining machine. The mining machine rides on the top edges of the conveyor system which stretches the width of the coal block. The mining machine traverses the coal face, removing coal, and the mined coal falls into the conveyor. As the coal is mined, the roof supports advance, moving the conveyor and mining machine forward against the coal face and allowing the roof to collapse into the mined-out area.

The Environmental Protection Agency advocated a modified method of longwall mining, termed longwall stripping, to recover coalbeds under shallow cover which would take the place of surface mining.

In longwall stripping, a trench is excavated along a section of the coalbed cropline and an entry is driven from the trench into the coalbed for a distance of 200 to 250 feet. The longwall mining equipment would be set up in the entry and mining would commence, recovering coal from the full length of the entry. As mining continues, the trench would be lengthened and material from the newly excavated area would be returned to the initial area of the trench, backfilling as mining continues. Overburden would subside into the 200- to 250-foot-long mined-out area with, theoretically, a minimum of surface vegetation disturbance.

Longwall stripping holds promise as an extraction method for some of the 4- to 10-foot thick coalbeds overlain by competent strata that occur in the Eastern United States. However, new mining equipment and roof control methods would have to be developed to mine coalbeds under thin, incompetent cover such as occurs in the Northern Great Plains Region, particularly thick coalbeds.

Other modifications of the longwall mining system, top slicing, sublevel caving, and sublevel caving in two lifts, have been tried in Europe and may have application in the Northern Great Plains.

It must be stressed that such thick-bed mining techniques do not entail off-the-shelf equipment and methodology in the United States. It will take a research and development effort of 5 to 10 years duration merely to prove the applicability of such advanced coal mining systems in this country, and particularly to geologic conditions existing in the Northern Great Plains. However, even if such systems are proven technically feasible, there is no guarantee of the economic viability of commercial-scale operations. European mining systems use more timber than in domestic operations, they are more labor intensive, and labor is less expensive than in this country.

Following is a brief description of thick-bed coal mining methods used in France which may have potential application in the Northern Great Plains.

Top Slicing

Top slicing has been used in France for many years to extract coalbeds in excess of 30 feet thick. Mining consists of driving entries and establishing a face for extracting the coal in descending slices, beginning with the uppermost portion of the coalbed, hence the name top slicing. As the top slice is mined, woven mats and screening are placed on the floor and the rock above the coal allowed to cave behind the face after the coal has been extracted. The matting then forms the roof of the next lower slice, containing the caved rock and inhibiting it from interfering with coal extraction. The procedure is repeated for each succeeding slice until the entire coalbed has been mined. See figure 7.

Difficulties were encountered in attempts to mechanize this mining system. Also, control and maintenance of the entries, which must be enlarged vertically to accommodate descending slices, represent a high proportion of the production cost of the coal. Such problems encountered in top slicing led to development of other methods of recovering thick coal beds.

Sublevel Caving

Sublevel caving consists of first driving entries and establishing a longwall face at the bottom of the coalbed. Longwall machines mine approximately an 8-foot slice of coal which is removed by a conveyor next to the face. A wire net is placed under the roof cut by the mining machine and above the hydraulically operated roof supports, an expensive operation. The purpose of this netting is to contain the fractured coal roof above the supports and to control sublevel caving at the gobside of the face (mined-out area). Coal above this bottom slice or sublevel is recovered on the gobside of the supports by induced caving. Windows are opened in the wire netting to regulate coal influx. This coal is removed by a conveyor on the gobside of the supports. See figure 8.

Roof supports are currently double-action props with monolithic roof bars with an articulated prop and bar ("banana") attached to the rear of the roof bar to act as a shield on the gobside. Conventional

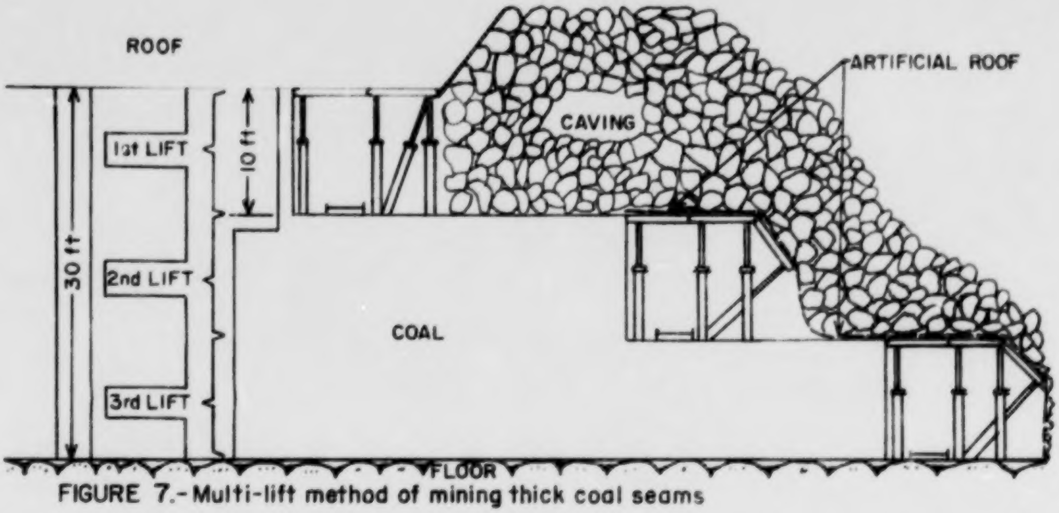
ROOF
ARTIFICIAL ROOF
CAVING
1st LIFT
10 ft
30 ft
2nd LIFT
COAL
3rd LIFT
FLOOR

FIGURE 7.- Multi-lift method of mining thick coal seams

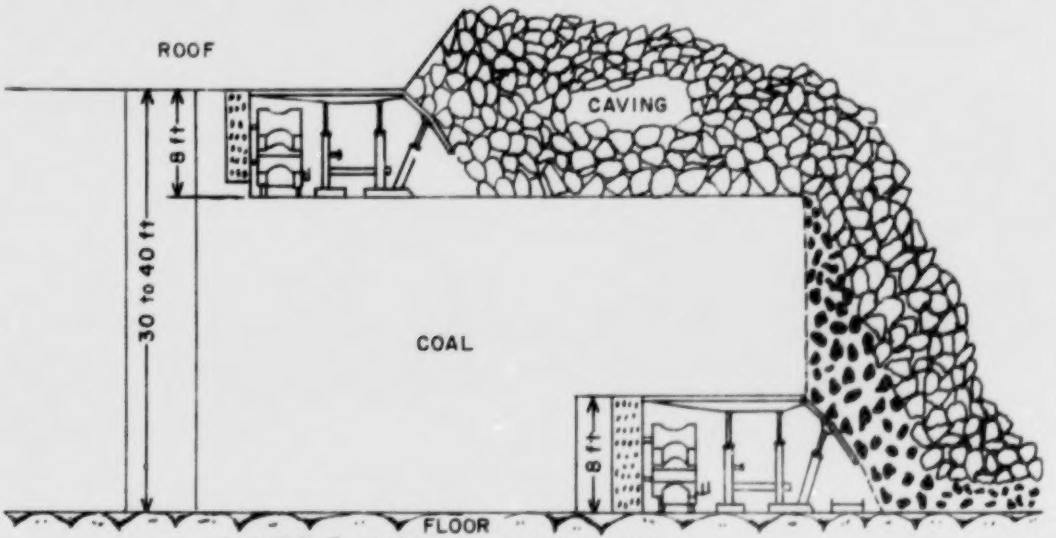
ROOF
CAVING
8 ft
30 to 40 ft
COAL
8 ft
FLOOR

FIGURE 9.- Sublevel caving in two lifts

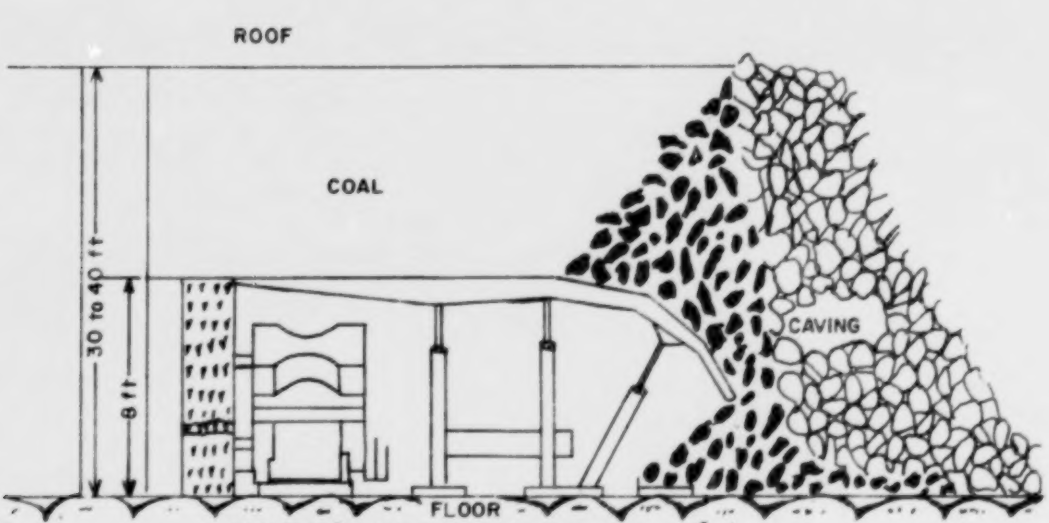
ROOF
COAL
30 to 40 ft
8 ft
CAVING
FLOOR

FIGURE 8.- Integral sublevel caving

longwall supports are not particularly appropriate in this application in light of very significant relative movements of the roof and floor. In addition to lateral movement, there is considerable displacement of the face and roof toward the gob. For this reason, the face is advanced either horizontally or slightly descending.

Problems may be encountered with excessive sloughing or spalling of coal at the face, undermining the stability of the roof. The face conveyor and supports must, therefore, be advanced toward the face immediately after the machine has mined the coal to prevent deterioration of the roof.

The caving or drawing operation is the most delicate portion of mining and requires specially-trained miners. Coal is recovered through windows cut in the wire netting. If the coal will not cave by itself and cannot be induced to do so by "pumping" the banana bars, it must be shot down with an explosive charge. In order to control the caving for even drawdown to insure the best recovery with the least dilution with waste rock, several passes may be required down the line of windows, each one being resewn after drawing coal through it if the caved material is fine-grained. The roof of the coalbed is reached when there is a change in color of the caved material. The slightest sign of instability behind the supports can preclude full recovery of the coal.

Conventional dust-suppression devices are used on the mining machine, but dust from the caving operation can be a problem. Plastic sheeting or plastic-covered wire netting is often used to prevent dust infiltration, as well as manifolds of sprays attached to the banana bars. However, low-pressure water infusion into the coal ahead of mining through a series of long holes has proven the most effective method of dust suppression and is widely used on conventional longwall faces in France.

As in top slicing, control and maintenance of entries are the most important problems encountered due to the great pressures on support systems in extracting a thick coalbed. Careful design of the mining operation is critical.

Recovery by sublevel caving under favorable conditions is comparable to conventional longwall, that is, 80 to 85 percent of the coal in place. It may be used in coalbeds equal to or greater than 18 feet thick.

Sublevel Caving in Two Lifts

This method of extracting thick coalbeds is a combination of top slicing and sublevel caving. First, entries are driven and a face is established at the top of the coalbed as in top slicing, except matting is not used on the floor. Then, more entries are driven, and a second face is established at the bottom of the coalbed; mining on this level proceeds as in sublevel caving described in the previous section. The primary purpose of the top slice is to destress the coal to avoid the displacement problems encountered at the face in sublevel caving. Wherever possible, using two lifts is avoided to eliminate the development and setup costs of the first face, the top slice. See figure 9.

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Coates, D. F., T. S. Cochrane, and G. Ellie. Three Mining Methods for Vertical, Inclined, and Thick Coal Seams Used in France. Can. Min. and Met. Bull., v. 65, No. 722, June 1972, pp. 70-76.

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In Situ Coal Gasification

In situ or underground coal gasification is a method of extracting the energy potential of a coalbed by burning the bed in place and extracting the low-Btu gas produced by the combustion process.

Large-scale experimental work on in situ coal gasification has been undertaken in the United States, England, France, Belgium, Italy, and the U.S.S.R. While the first reference to in situ gasification technology occurred in 1868, most of the field experimental work was done in the 15-year period between 1945 and 1960. Experimentation in the Soviet Union reached the stage where the extracted gas was used for large-scale generation of electricity.

The usual method of preparing the coal for gasification is to intersect the bed with a number of boreholes, connect the holes by either directional drilling or hydrofracturing, and then ignite the bed. Air or oxygen is pumped down one or more holes to aid combustion, and gas is extracted from other holes.

Currently, the U.S. Bureau of Mines is conducting a field experiment on in situ gasification at Hanna, Wyo., in a 25- to 30-foot thick coalbed 400 feet below the surface. While gas is being generated by the combustion process and recovered at the surface, it is too early to determine the success of the experiment.

EVALUATION OF MINING METHODS: SURFACE VERSUS UNDERGROUND

Introduction

Considerable controversy surrounds the use of surface-mining techniques for coal extraction in the Northern Great Plains Region. Some individuals and groups are advocating the use of underground mining as an alternative for surface mining to avoid what has already happened in Appalachia. The climatic, topographic, and geologic differences between Appalachia and the Northern Great Plains, which whould be obvious, require the use of considerably different methods of evaluation and comparison. Different types of surface mining are now and will in the future be used in the Northern Great Plains Region. Surface and underground mining methods are evaluated as regards the environment, manpower, resource conservation, and economics. The evaluation utilizes the prevailing conditions currently existing in the Northern Great Plains Region, including climate, topography, geology, environment, land, water, and human.

Environmental Aspects

Coal mining, like every action of man, has an impact upon the environment. Because of the intricate and interrelated biological, chemical, and physical balances in nature, it is often difficult to determine, let alone predict, the extent of such impacts. Nevertheless, coal must be extracted from the ground to satisfy the energy requirements of our Nation. This is not to suggest that we should abandon our environment and produce coal in a reckless manner. It is possible to simultaneously satisfy our energy needs and preserve our environment in a responsible manner. However, the accomplishment of this task requires a knowledge of the environmental impacts brought about by current coal mining practices. Research is required to further delineate these impacts, develop reclamation techniques, and advance the state-of-the-art of coal extraction.

Air Pollution

The most common form of air pollution associated with coal mining is airborne dust, particularly in a semiarid climate where high winds are common.

Underground coal mining, due to the confined working area, does not pose a problem to ambient air quality in itself, except around surface facilities and dump areas. Careful design and maintenance of these facilities will prevent airborne dust from becoming a problem.

To alleviate dust pollution associated with surface mining requires proper planning. Haul roads and traveled facilities must be surfaced with asphalt, oiled, or kept damp with water. Oiling of roads may not be the best dust suppression method since many areas come in close contact with surface and ground water. Mined areas need timely reclamation and seeding to prevent wind erosion of spoil piles. Planning is essential in designating areas of potential dust pollution and utilizing the best methods possible to keep airborne dust at an acceptable level.

Coal exposed to the atmosphere will ignite by spontaneous combustion and release smoke containing air pollutants. This can occur before, during, or after mining, and underground mining operations have greater problems from spontaneous combustion than surface mines. Proper burial of exposed coalbeds in a surface mine excludes the danger of coal ignition, whereas land subsidence over underground mines may develop fractures to the surface, allowing air in the underground workings, resulting in ignition. Burning coal in abandoned underground coal mines is difficult or impossible to extinguish and extremely hazardous to life.

Another potential source of air pollution is the presence of a coal refuse bank, commonly called a gob pile or dump, which consists of rejected rock, waste material, and other impurities accumulated during the mining of coal. Airborne dust and spontaneous combustion are common in this area. Such material is buried beneath the spoil during surface mining, but the accumulation of such material on the surface is common practice in underground mining. Proper design and maintenance of refuse banks or the return of this material to mined-out workings is necessary. However, returning this material underground is costly and will require some modifications to the mining technique.

Water pollution will be discussed under the surface and ground water headings.

Surface Features

The physical surface of the land and the vegetative cover will both be affected by coal mining. This impact is more visual during surface mining, but the effects are largely known and can be mitigated by good reclamation practice. However, surface subsidence, the inevitable result of underground mining over large areas, is highly unpredictable and is expensive to adequately control at the present time. Subsidence is usually a long term problem, essentially withdrawing the surface from productive use.

Land Surface

Surface subsidence following extraction of coal by underground mining methods is a most pervasive form of pollution. Damage to the land surface includes fissures, sinkholes, cave-ins, and an irregular lowering of the land. Horizontal displacement, combined with vertical subsidence, will damage surface structures, alter surface and ground water drainage patterns, and allow water and air access to the underground workings and, therefore, may promote air and water pollution which will affect plant and animal life. Subsidence can also make plowing and traversing of the surface impossible, and will depress land values by eliminating this land from future development.

Subsidence, particularly in unconsolidated sediments such as those overlying the coal in the region, is the inevitable result of underground coal mining over large areas.[1/] It is a fact of life for the present

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[1/] TRW Systems Group. Underground Coal Mining in the United States--Research and Development Programs. Off. of Sci. and Tech. Rept. No. 13497-6001-RO-00, Wash., D.C., June 1970, p. C-1.
Woodruff, S. D. Methods of Working Coal and Metal Mines--Ground Support Methods. Pergamon Press, Inc., New York, v. 2, 1966, p. 86.

because there are currently no known economic preventative measures other than to leave the coal untouched. This may be necessary in those cases where subsidence in any form is intolerable.

Currently, the most prevalent method of mining coal underground in the United States is the room-and-pillar type where blocks of coal are left in place to provide roof support for worker safety and to provide support for surface features. However, these pillars will deteriorate over time and eventually fail, whether in one or one hundred years after the workings are abandoned. The highly unpredictable nature of subsidence following partial extraction of the coal is an essential consideration in land use planning.

Total extraction, whether by longwall or the pulling of pillars, allows subsidence to run its course more quickly, leaving only strata compaction remaining to achieve stabilization of the surface. In addition, the proper planning of total extraction will result in a sequential lowering of the land surface to predictable levels. Subsidence still occurs, but at least some control over its consequence is maintained. Controlled subsidence through total extraction of the coal is practiced in other countries, but time and experience will be required before such methods can be properly utilized in the United States, and particularly to unique conditions of the Northern Great Plains. Moreover, methods of total extraction are not universally applicable, but must depend upon favorable conditions at specific sites.

Another method of reducing the impact of subsidence is the backfilling, or stowing, of waste material in mined-out areas underground.

Backfilling is not currently practiced in the United States. As previously mentioned, backfilling is expensive. In addition, only about 15 percent of the material mined--coal, rock, etc.--is available for use as a fill material.[2] Therefore, suitable material such as sand and gravel would have to be obtained from another source. This source would likely be an open-pit operation on the surface which would pose its own environmental problems and would require reclamation. It must be remembered that backfilling with such material does not prevent subsidence, but merely reduces its effects. The supporting ability of such fill material is not developed until it is substantially compressed. Even under the best conditions, the surface may subside by about 50 percent of the coalbed thickness.[3] Although theoretically feasible, effectively backfilling a mined-out underground void with material such as concrete or solid steel to prevent subsidence would be prohibitively expensive and would lead to a tremendous increase in cost to the ultimate consumer.

Surface mining of coal in the Northern Great Plains is by either the area strip or open pit method. Vegetation is removed and disposed of, topsoil is removed and stockpiled, and the unweathered overburden--soil and rock--which covers the coal is overturned and exposed. Surface topography and drainage patterns and soil conditions are altered during the mining process. The extraction of thick, near-surface coalbeds, where the volume of coal removed exceeds the volumetric expansion of the broken overburden, will leave a depression in the ground surface.

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[2] Page C-7 of first work cited in footnote 1.

[3] Courtney, W. J., and M. M. Singh. Pneumatic Stowings: It Must Be Looked at Now. Coal Min. and Proc., v. 11, No. 2, February 1974, p. 27.
Panek, L. A. Program for Control of Surface Subsidence. U.S. BuMines Denver Mining Research Center Prog. Rept. No. 10011, Denver, Colo., 1973, pp. 6 and 15.
Pages 84 and 119 of second work cited in footnote 1.

The semiarid climate--less than 15 inches of annual precipitation--lessens the problem of erosion, but increases the problem of revegetation. However, high winds may cause sheet erosion and infrequent, but violent, storms will contribute to sheet erosion, gullying, and stream channel erosion, the product of which is sediment.

The impacts of surface mining on the land surface are known and can be controlled by careful planning and reclamation so that land disturbance is of relatively short-term duration. Surface topography and drainage patterns can be returned to approximate original contours depending upon requirements of the future land use plan. Proper compaction and grading to a planned surface will control erosion. Terracing, contour furrowing, and other erosion controls are all applicable, and it is also important that a vegetative cover be established as soon as possible to stabilize the surface and prevent wind and water erosion.

Vegetation

As stated previously, the vegetative cover is removed in the process of surface mining and the overburden is overturned, exposing unweathered materials which may be lacking in adequate plant nutrients and microbial populations. Acidic material will not be a problem in the semiarid West; rather, alkaline and saline materials, now present in undisturbed areas, will be present, possibly accompanied by heavy metal phytotoxicants. Erosion, caused by both water and wind, must be controlled to allow young plants to survive.

Revegetation is now and must be an integral part of the reclamation process. It is necessary for productive use of the land, protection against erosion, and preservation of aesthetic values. To provide an adequate soil for revegetation, topsoil will be saved and should be used as a surface covering for graded spoil as soon as possible after mining to prevent leaching out of the active soil constituents. In addition, toxic materials and those materials detrimental to water infiltration and soil aeration will have to buried beneath the spoil.

Properly seeded and maintained grasses and legumes will build up the organic matter level of the soil. However, water, not soil fertility, is the limiting factor in the West. The water infiltration and retention potential of surface mine spoils could provide more water for vegetative growth if spoil disposal is accomplished in an acceptable manner (chemically and physically). Sublimation of snow and evaporation of surface water must be lessened so sufficient moisture is available for revegetation. Various dryland farming techniques will be applied and erosion control measures will be necessary until the vegetative cover is established. Research is continuing on plant species, both native and imported, to achieve the best growth requiring the least maintenance. Success in the revegetation of mined land will have a beneficial effect on the livestock industry and wildlife habitat.

Underground coal mining has little direct effect upon vegetation except around the surface facilities. Indirect effects relate to subsidence. Capture or rerouting of surface or ground water can deprive vegetation of needed moisture. Fumes from an underground mine fire can inhibit and destroy vegetation, and surface damage from subsidence can directly affect vegetation. Control measures are directly related to control of surface subsidence.

Water Related Aspects

Surface and ground water are closely related and both will be affected by coal mining in the Northern Great Plains. Pollution by acid mine drainage will not be a problem in the West because of the low sulfur content of the coals and the semiarid climate. Sediment discharge can be controlled. The water infiltration and retention capability of cast overburden may be beneficial to surface and ground water supplies if quality is not harmed and infiltration is increased.

Surface Water

Subsidence resulting from underground coal mining can alter natural or artificial drainage systems and actually capture surface water. Drainage from underground mines, whether originating as surface or ground water, is a major contributor of acid pollution in the East and Midwest. Drainage in the Northern Great Plains will be mostly alkaline. Any local acid drainage will likely be neutralized due to the alkaline nature of the soils in the region.

Coal refuse banks contribute to surface water pollution via sedimentation and the leaching out of toxic materials unless properly reclaimed. Improperly maintained surface facilities and haul roads will likewise contribute to sedimentation.

The major sources of acid pollution in the East and Midwest are underground coal mines, contour strip and auger mines, coal preparation plants, haul roads, and coal refuse banks; whereas it appears that area-type surface mines, typified in Indiana, seldom contribute to acid pollution.[4] The scarcity of water in the West indicates that water may be reduced in terms of quantity, and that a small amount of pollution may have a more deleterious impact on water uses than the same amount would in the Eastern United States.

Properly segregated, cast overburden contains voids which are capable of storing large amounts of water which will add to the ground water supply and to surface water availability. Cast overburden also tends to reduce storm runoff because of greater water infiltration rates than surrounding compacted areas.[5] As mentioned previously, this water infiltration and retention capability of cast overburden provides for increased soil moisture for vegetation.

Siltation, the product of erosion, has a detrimental effect upon plant and animal life. It is more of a problem in areas of rugged topography such as in the East than in the rolling plains of the West. Careful planning and the use of erosion control techniques will minimize the impact of sediment discharge in the semiarid Northern Great Plains.

Ground Water

Subsidence from underground coal mining can capture, reroute, and pollute ground water. The degree of influence will depend upon several

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4/ Corbett, D. M., and A. F. Agnew. Coal Mining Effect on Busseron Creek Watershed, Sullivan County, Indiana. Indiana Univ. Water Resources Research Center RI No. 2, Bloomington, Ind., 1968, pp. iv and 156.

5/ Agnew, A. F. A Quarter to Zero--Surface Mining and Water Supplies. Min. Cong. J., v. 52, No. 10, October 1966, p. 39.

Corbett, D. M. Water Supplied by Coal Surface Mines, Pike County, Indiana. Indiana Univ. Water Resources Research Center RI No. 1, Bloomington, Ind., 1965, pp. 2-3, 8, 30, 34.

Pages 136 and 157 of work cited in footnote 4.

physical factors, including the position of the mine in relation to the water table and the degree of subsidence.

Little is known of the impact of surface mining on ground water except for the infiltration and retention capabilities of cast overburden augmenting ground water supplies. There will be some local impact on ground water supplies, but the effect upon regional flow patterns is not known.

Mineral Resources Conservation

Resource conservation dictates the use of the most efficient mining methods that current technology allows. Various coal mining techniques, whether surface or underground, have specific applications under conditions for which they were developed. Surface mining offers the efficient extraction of near-surface coalbeds, whether thick or thin. Underground mining with techniques currently available requires certain geologic conditions for successful application, and current technology does not permit the extraction of coalbeds much in excess of 10 feet thick without waste.

New mining techniques are being investigated, but research and development in this field normally take years. The research and development phase for underground mining technology has been about 10 years, with another 20 years required for widespread development. For example, the period 1950 to 1960 corresponds to the research and development phase of longwall mining in the United States. The installation of longwall equipment has increased since 1960, but widespread application in coal fields for which geologic conditions allow its use is sometime in the future.[6] Geologic conditions in the Northern Great Plains will have to be investigated to determine the applicability of longwall mining methods.

Coal Resources

On a national basis, underground coal mining in the United States currently averages about 57-percent recovery of the coal being mined.[7] This factor does not apply to thick beds where appreciable coal is left in the roof, floor, or both, because of inadequate technology and equipment to maintain face heights much greater than 10 feet. The 57-percent figure was developed for room and pillar mining, the most common form of underground mining in this country. It is possible by mining the pillars, following the initial phase of mining, to realize up to 85-percent recovery in a coalbed up to about 10 feet thick, thus achieving recovery equivalent to that expected from longwall mining. Total extraction--longwall or pulling pillars--does not appear to be feasible in thick beds, where adverse geologic conditions exist, where pillars are required for ventilation control or surface support, and where other factors dictate the leaving of blocks of coal.

Therefore, room and pillar mining in a 30-foot coalbed would recover about 57 percent of a 10-foot slice of this bed, leaving unmined the remaining 20 feet of coal. This would be equivalent to 19-percent recovery of the entire coalbed. Similarly, if 85-percent recovery of this 10-foot slice is realized by longwall methods, recovery calculated over the total thickness of the coalbed would only amount to about 28.3 percent. This example illustrates the gross contradiction to the concept of resource conservation when domestic underground coal mining technology is applied to a thick coalbed. Figure 10 demonstrates the effect of bed thickness on percentage recovery of coal by current mining methods.

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[6] Page A-7 of first work cited in footnote 1.

[7] Lowrie, R. L. Recovery Percentage of Bituminous Coal Deposits in the United States. U.S. BuMine RI 7109, Wash., D.C., 1968, p. 1.

Another geologic condition adverse to underground mining is near-surface coal where the strata above the coal is not strong enough to provide competent roof conditions for mining and is more difficult to control in longwall mining where roof control depends upon the cantilever effect of strong strata immediately overlying the coalbed. Mining one coalbed with others closely spaced above or below may preclude the mining of these other beds because of the pressure distribution in the intervening strata. Other conditions, such as split beds and bad roof, limit the ability to mine underground.

Surface mining in the Northern Great Plains is by the area and open pit methods, generally yielding a recovery of 80 to 95 percent of the coal in place. Thick coal beds, multiple beds, thin beds, and split beds do not preclude good recovery of coal by surface mining. Limitations of equipment on depth of mining and surface features which cannot be moved or rerouted offer the main obstacles which serve to limit surface coal mining. Of great concern to present and future generations is the maximum recovery of the Nation's coal resources, including the thick, near-surface coalbeds in the Northern Great Plains Region. Surface mining is currently the only method of

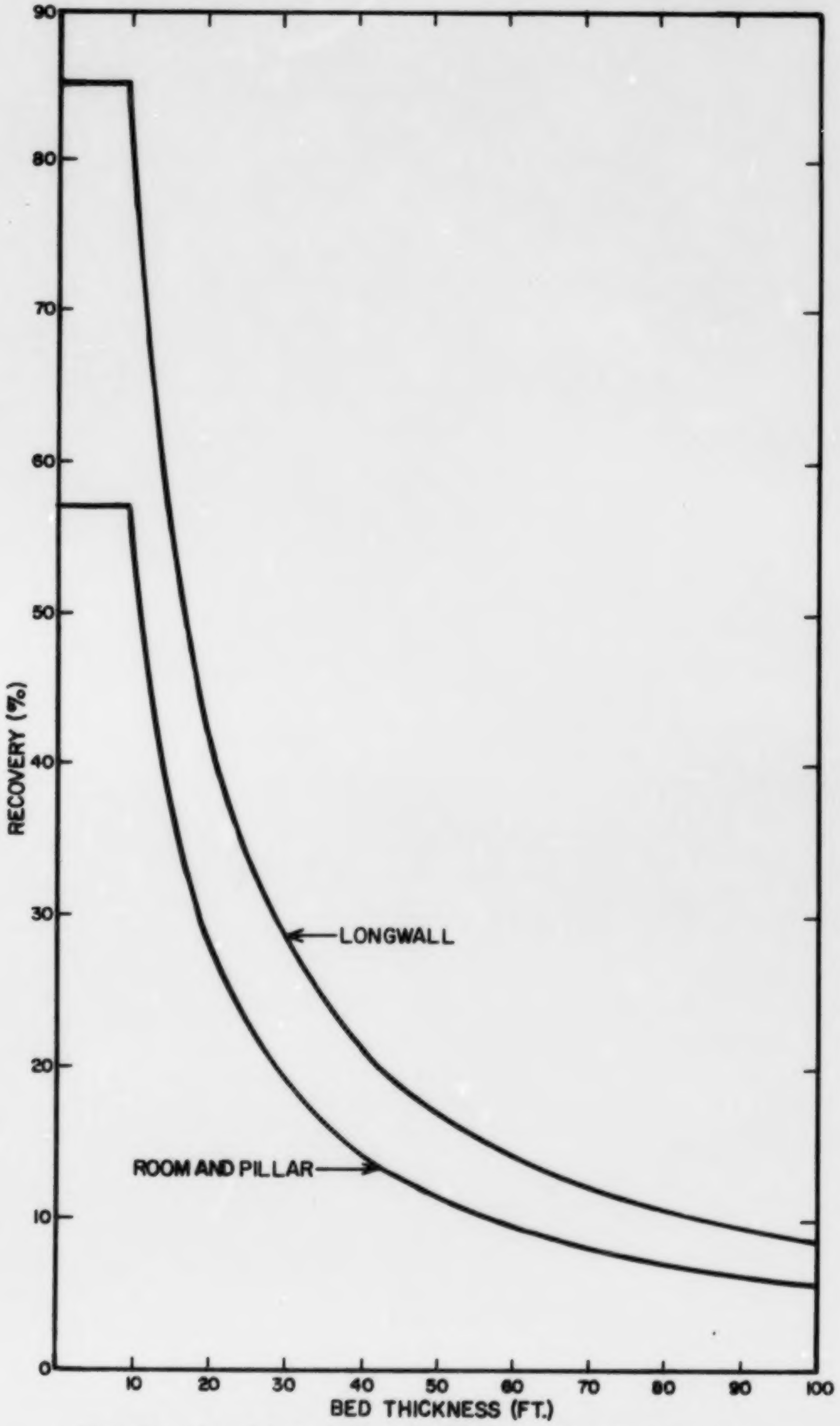

FIGURE 10.- Effect of Bed Thickness on Coal Recovery.

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efficiently extracting such coal without tremendous waste of a natural resource.[8]

Conflicting Mineral Resources

The primary mineral resources which pose a conflict with coal development in the Northern Great Plains area are clay, oil and gas, sand and gravel, and uranium. The scope of such conflicts is not well defined at this time, but the extraction of coal may preclude or make recovery of another mineral more difficult, and vice versa. Areas of potential mineral resource conflict are shown on plate B-12. Identification and resolution of conflicts will require investigations of the individual deposits.

Manpower Related Aspects

Any discussion of coal mining would be incomplete without including the impacts on, and by, manpower. Different mining methods will exhibit inherent differences in relation to manpower safety, productivity, and availability.

Surface mining of coal is safer than underground mining, is less labor intensive, and requires less specialized worker skills, and therefore availability of trained manpower, a problem in the Northern Great Plains, is less of a constraint to increased coal development.

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[8] Extraction of Energy Fuels Panel. Extraction of Energy Fuels--Primary Extraction of Coal. Prep. for Committee on Energy R and D Goals, Fed. Council for Sci. and Technol., Wash., D.C., September 1972, Chapt. 5, p. 35.

Glass, G. B. Wyoming in Western Coal. Coal Age, v. 78, No. 5, mid-April 1973, p. 200.

Noble, E. A. A Geologist's View of Strip Mining in Wali, Mohan K. (ed.), Some Environmental Aspects of Strip Mining in North Dakota. North Dakota Geol. Survey Educational Series No. 5, Grand Forks, N. Dak., 1973, p. 60.

Pennsylvania State University. An Analysis of Strip Mining Methods and Equipment Selection. OCR R and D Rept. No. 61, Interim Rept. No. 7, Contract No. 14-01-0001-390, May 29, 1973, p. 105.

Sullivan, G. D. Land Reclamation Problems and Their Effect on the Nation's Coal Industry in Natural Gas, Coal, Ground Water. Western Resources Conf., 8th Ann., Golden, Colo., 1966, p. 186.

Health and Safety

Coal mining is a hazardous occupation. The following graphs (fig.11,12) compiled from data published annually in U.S. Bureau of Mines Information Circulars, illustrate the relative injury statistics for the various methods of mining coal for the period 1960 to 1970. The number of injuries, both fatal and nonfatal, per million man-hours shows little if any improvement, while the injuries per million short tons of coal production show gradual declines. This discrepancy is due primarily to increases in mechanization and production technology. The hazards remain, but fewer miners are exposed to them. The Federal Coal Mine Health and Safety Act of 1969 should serve to reduce hazards, but insufficient time has elapsed to determine the impact of this law. However, one thing is clear--*legislation is not enough.* An effective safety program which includes manpower training is *absolutely essential.*

It is clear from the graphs on injury statistics that surface mining is less hazardous than is underground mining. Surface mining, particularly as practiced in the West, is comparable to the heavy construction industry in regard to injury experience.[9]

Besides the obvious safety hazards of a subsurface environment, underground coal mining also poses certain health hazards, the most well known being pneumoconiosis, a chronic respiratory disease. Approximately 15 percent of the underground coal miners in the United States

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[9] Moyer, F. T., and M. B. McNair. Injury Experience in Coal Mining, 1970. U.S. BuMines IC 8613, Wash., D.C., 1973, p. 26.

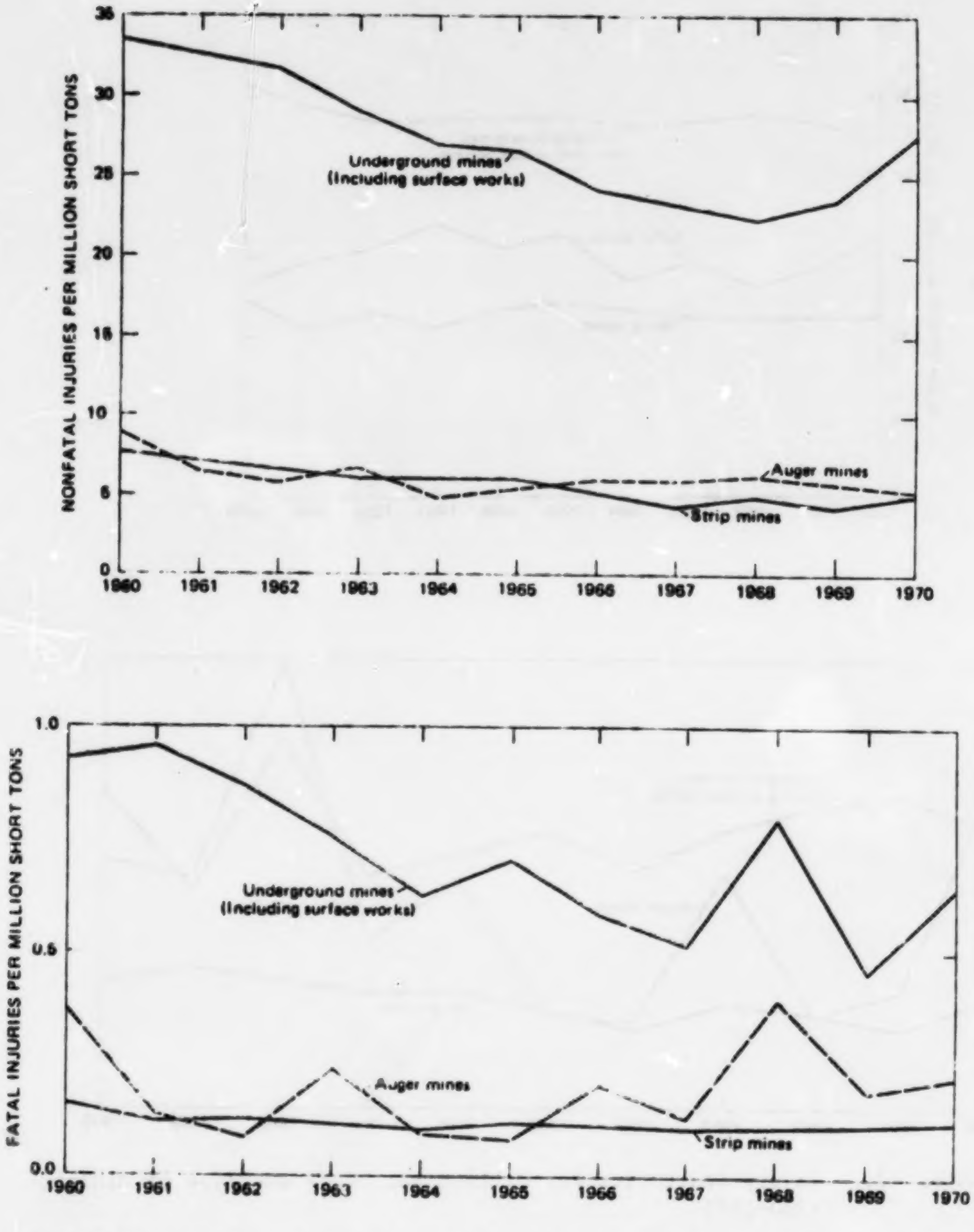

FIGURE 11. - Injury Statistics for Various Types of Coal Mining, 1960-1970.

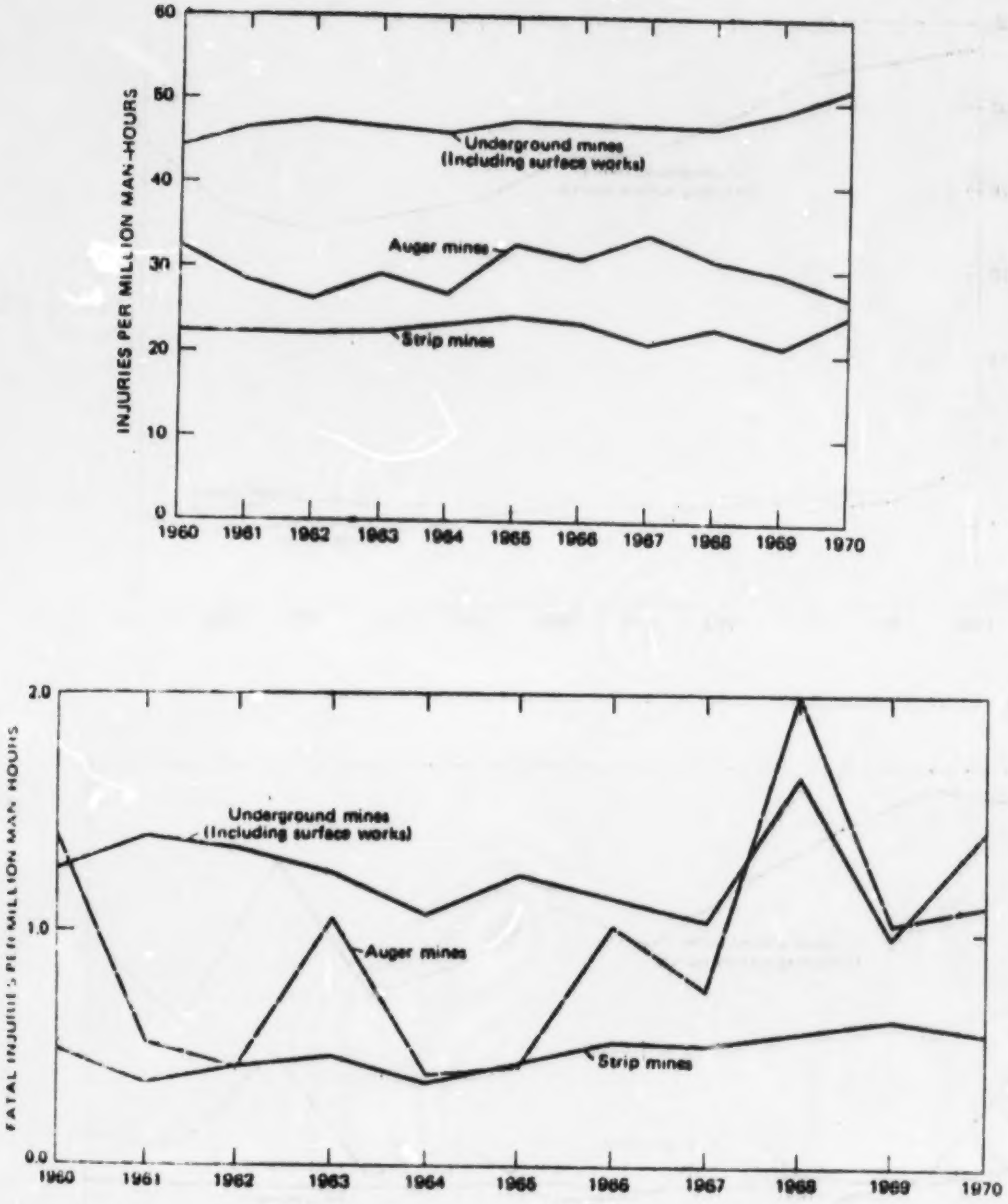

FIGURE 12. - Injury Statistics Per Million Man Hours and Type of Mining, 1960-1970.

are afflicted with this disease.[10] The increase in levels of respirable dust due to modern mining machinery designed for high production rates is the major reason for the great number of occupational respiratory diseases in underground coal mining in comparison to the rest of the working population.

Availability

Coal mining, particularly underground mining, faces a serious shortage of trained manpower. Whereas surface mining, in general, utilizes the skills of heavy equipment operators and can therefore draw upon the construction industry for its manpower requirements, underground mining requires more specialized skills.

In addition to the current shortage of engineers and technicians, the highly-mechanized underground coal mining industry requires miners familiar with the specialized equipment and with the rigorous new requirements for health and safety. Additional manpower will also be required to replace workers lost by retirement, death, and transfer to other work.

Recruiting coal miners, particularly underground, will be a challenge because of the poor public image of the industry and the hazardous nature of the work. Also, the coal mines are usually located remote from readily accessible urban areas. The aversion of many capable workers to underground coal mining must be overcome before operations can be expanded.

An important consideration when comparing surface and underground coal mining is the manpower requirements for each mining method. Of the 595,386,000 tons of coal produced in the United States in 1972, 304,103,000 tons, or 51 percent of the total, were produced from underground mines.[11] However, of the 149,265 men employed in producing this coal, 112,252 men, or 75 percent of total manpower, were employed in underground mining.[12] This large manpower requirement for underground versus surface coal mining poses a real problem in light of the present availability of trained miners, and introduces us to the next topic--productivity.

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[10] Page 6-61 of first work cited in footnote 1.

Productivity

As mentioned in the previous section, underground coal mining uses 75 percent of the industry's manpower to produce 50 percent of the Nation's coal. Productivity is a measure of the efficiency of utilization of manpower and equipment. The average productivity of coal production by underground mining in the United States in 1972 was 11.91 tons per man per day. In contrast, the average productivity of surface coal mining, excluding auger mining, during the same year, was 35.95 tons per man per day.[13] In addition, the average productivity of surface mining in 1972 in Wyoming, Montana, and North Dakota was 83.84 tons per man per day. Therefore, fewer men are required to produce a given quantity of coal by surface methods than by underground methods. Figure 13 illustrates underground and surface mining trends in productivity and employment.

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[11] U.S. Bureau of Mines. Coal--Bituminous and Lignite in 1972. Mineral Industry Survey, Nov. 15, 1973, p. 4.

[12] Page 42 of work cited in footnote 11.

[13] Page 42 of work cited in footnote 11.

BITUMINOUS COAL AND LIGNITE
UNDERGROUND AND SURFACE MINING TRENDS

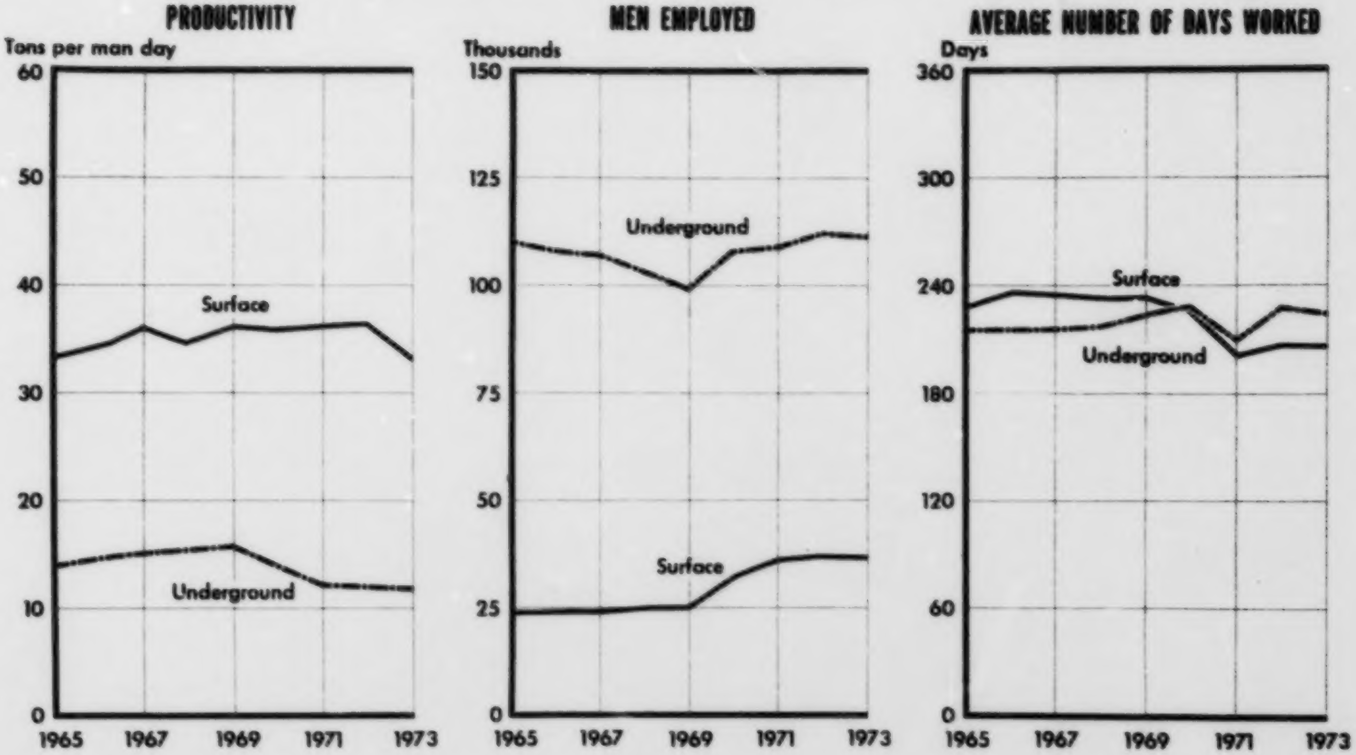

FIGURE 13.

The difference in productivity is a direct consequence of the working conditions and reflects the relative hazards of the two basic mining methods. Surface coal mining is capable of utilizing large, efficient earth-moving machinery and has benefited from recent developments and growth in the heavy equipment industry. Surface mining is flexible enough to accommodate changing geologic conditions governing coal occurrence and is amenable to the use of differing types of earth-moving equipment should the need occur.

In contrast, underground coal mining is necessarily confined to a limited working area, is often inflexible to changing geologic conditions and equipment usage, and is labor intensive. Hazardous working conditions require certain preventive measures which prohibit full equipment utilization, often resulting in mismatches of equipment capabilities.

Economic Aspects

The relative economics of underground and surface coal mining are reflected in the respective selling prices of the coal produced. The average reported selling price, f.o.b. mine, of coal from underground mines in the United States in 1972 was $9.70 per ton, while the price of surface-mined coal was $5.48 per ton (excluding auger mining). In addition, the average reported selling price of surface-mined coal in the states of Montana, North Dakota, and Wyoming was $2.71 per ton, reflecting the abundance of thick, near-surface coal in the Northern Great Plains which is not amenable to underground extraction.[14]

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[14] Page 68 of work cited in footnote 11.

The economic advantage enjoyed by surface mining is due to greater productivity of men and machinery, lower capital requirements, and less hazardous working conditions, and results in lower costs to the ultimate consumer. Since the enactment of the Federal Coal Mine Health and Safety Act of 1969, underground coal mining has been faced with increasing costs associated with ever-stricter regulations governing the working environment. The overall impact of these regulations has not yet been defined, and the possibility of overcoming the increase in costs through greater mechanization and the development of advanced mining techniques will require time to evolve. Trends in underground and surface mining production and value are shown in figure 14.

The capital requirements of opening a new underground coal mine are $30 million to $40 million, versus $20 million to $30 million for a new surface coal mine. In addition, depending upon equipment availability, it takes about five years before the underground mine is in full production, versus two to three years for a new surface mine.[15]

Summary and Conclusions

With current technology, coal mining has a definite impact upon the environment. Surface mining techniques, area and open pit being considered, result in removal of the vegetative cover and overturning of the overburden materials overlying the coal. Underground mining over large areas, although it results in little direct impact upon the environment, inevitably leads to surface subsidence which can have a definite impact upon the environment.

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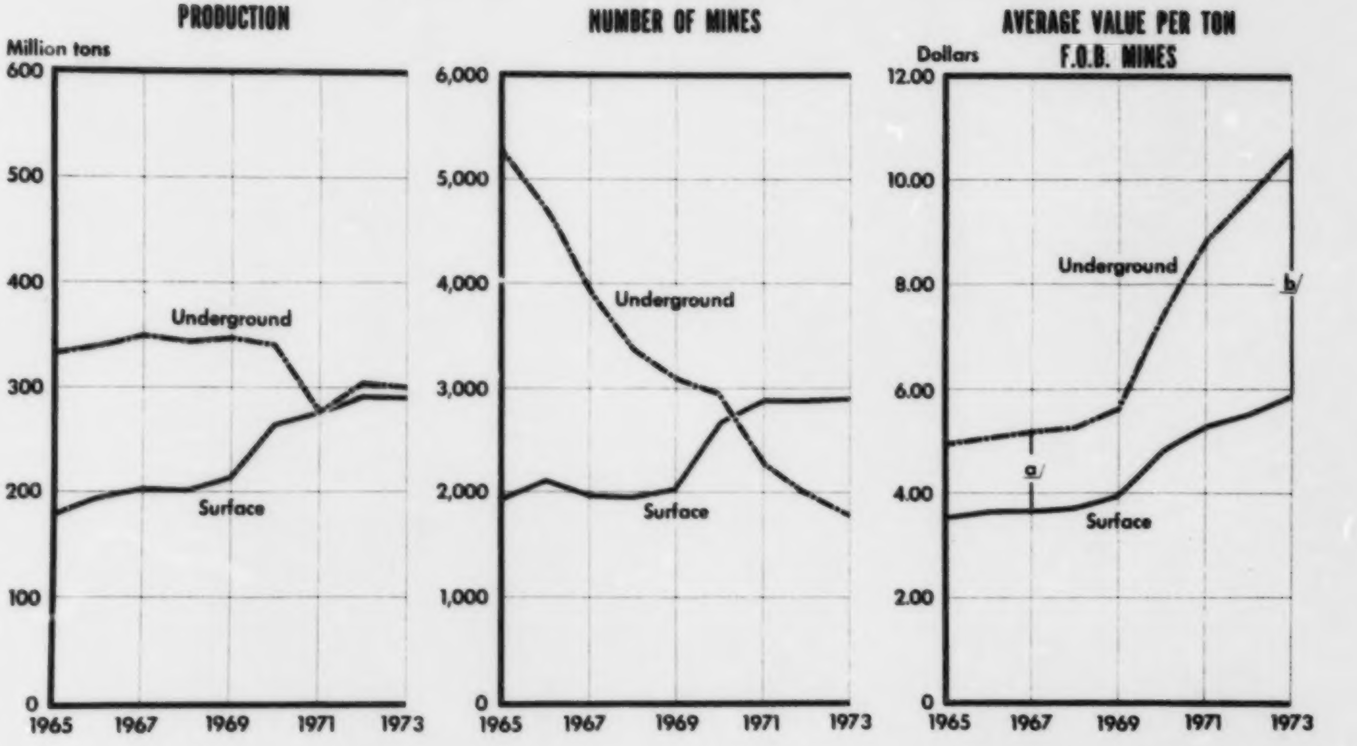
[15] McFeatters, D. U.S. Coal Reserves Offer No Miracle Cure for Crisis. Rocky Mountain News, Denver, Colo., Sun., Feb. 17, 1974, p. 36.

BITUMINOUS COAL AND LIGNITE
UNDERGROUND AND SURFACE MINING TRENDS



a/Average Spread 1965-1969: $1.50/ton

b/Average Spread 1973: $4.40/tons

FIGURE 14.

As we have seen from the report, there is no satisfactory preventive measure to eliminate subsidence under today's technology and realistic economics. However, either by working under current technology or making minor alterations in the mining and reclamation techniques, surface-mined land can be satisfactorily reclaimed to a productive use in the majority of cases.

Any decision on coal recovery method must, however, consider other factors besides the environment. Of considerable importance is the conservation of human lives and natural resources. Inefficiency and waste concerning the above mentioned factors relates to economics, which in turn affects the ultimate consumer. Surface coal mining, as practiced in the Northern Great Plains, is less hazardous and less labor intensive, less wasteful of a natural resource, and less costly in terms of dollars than underground mining.

Considering these various factors, surface coal mining was chosen as the major coal extraction technique to be used in the Northern Great Plains Region. This is not to say that underground coal mining will never be practiced in the region. The decision was based upon the current state-of-the-art of mining. We cannot satisfy demands for energy in a short-term framework by hoping to develop satisfactory underground coal mining techniques which require long-range research and development. Neither can we tolerate punitive legislation which gives underground coal mining an apparent economic advantage, because extracting coal in such a manner will be gained at the cost of more human lives and greater waste of a natural resource, as well as pervasive and long-term damage to our environment.

We must resolve the problems and expand our vision if we are to meet the challenges of today's demands for energy without seriously impairing tomorrow's demands for a safe and clean total environment. There are far too many interrelated factors to be considered to allow identification of the best mining method over and above surface mining in the West without unique (and accelerated) research into the methods and their impacts. At this point in time, surface mining offers lower cost coal, nearly complete extraction of near-surface coal, a relatively stable surface (versus subsidence) after mining, and a safer method of mining. For those deciding on mining in the next few years, surface mining appears to be the most appropriate method. If, however, the "economics" of energy production change, or if surface mining is shown to prevent either subsequent use of lands or subsequent mining of deeper coals, surface mining may become less attractive than it is now, even without appreciable advances in underground mining technology.

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CONSTRAINTS TO COAL DEVELOPMENT

There are numerous situations--constraints, that could act as a deterrent to increased coal production in the Northern Great Plains Region. Many of these will be discussed in the reports of the appropriate work groups. The following discussion will address constraints dealing with legislation affecting leasing-mining and potential constraints that could actually deter or inhibit mining.

Mining Laws

The leasing laws referred to here are the Federal and State laws relating to the location and patenting of mining claims. The Federal law is the Act of May 10, 1872, as amended (30 U.S.C. 21, *et seq.*).

The Federal regulations are contained in 43 Code of Federal Regulations (CFR), Part 3800. The State laws supplement the Federal laws and must be complied with.

Theoretically, the mining laws themselves present no constraint or deterrent for increased coal mining. The Act of August 13, 1954, Public Law 585, 83rd Congress (68 Stat. 708, 30 U.S.C. 521 et seq.), The Multiple Mineral Development Act, provides for development of separate deposits of both leasable and locatable minerals on the same tract of land. However, P.L. 585 did not take care of the problem of intermixed locatable and leasable minerals in the same deposit. This requires special legislation. In the case of uraniferous lignite (which may be found within the Northern Great Plains Resource Program region), this was solved by the Act of August 11, 1955, Public Law 357, 84th Congress (69 Stat. 679, 30 U.S.C. 541), which provided for development of such deposits.

As a practical matter, the location of mining claims could present constraints or deterrents for increased coal mining in several ways.

Legitimate Mining Claims

There may be a potential problem with locatable mineral deposits conflicting with coal deposits. For example, it is suspected that the uranium deposits being developed in the southern part of the Powder River Basin occur in the Fort Union formation, the same formation in which the coal occurs. P.L. 585 provides a means of resolving conflicts; however, where the locatable minerals are developed first, it is conceivable that operations for the locatable minerals would make later recovery of the leasable mineral (coal, in this case) more difficult, more expensive, or even impossible.

Uranium mill tailings could conceivably present a constraint for development of coal deposits underlying them. These tailings contain radium having a radioactive half-life of 1,600 years. Thus, these tailings need essentially perpetual care and maintenance. On national resource lands, mill sites located under mining laws are often used as sites for tailings disposal.

Nuisance Mining Claims

Mining claims are sometimes located for speculative and/or nuisance purposes without any real indication of the presence of a valuable locatable mineral. In some cases, the holders of such claims offer to sell such claims to coal developers. Such mining claims can safely be ignored, or, if necessary, legal action (private or government contest or court action) can be taken. Unless prevented by court order, development can proceed pending final legal action. Since the claims lack a valid discovery, proving the claims are invalid is not too difficult but may involve considerable periods of time. Essentially, this type of claim represents a nuisance rather than a real deterrent.

Proposed Legislation

In October 1973, the U.S. Senate passed Senate bill, S. 425, Surface Mining Reclamation Act of 1973. An amendment to section 612(b) of the bill would withdraw Federally-owned coal from surface mining if the surface is under private ownership.

The Bureau of Land Management and Geological Survey have developed data on the possible effects of the amendment to the Senate bill on the coal resources in the states comprising the study area.

Currently, there are 129 Federal coal leases in Montana, Wyoming, and North Dakota. No Federal coal lands are under lease in South Dakota. These leases cover 252,601 acres, of which 168,599 acres or 66.7 percent have private surface owners. Estimates of surface minable coal by the Geological Survey underlying the entire Federal coal lease area total 9,206 million tons. An estimated 5,974 million tons of Federally leased surface-minable coal underlie privately owned surface, and recovery by surface mining would be denied if the above mentioned amendment becomes law. This coal, because of the technology-economics of recovering thick, near-surface coalbeds, would not be available for mining until such time that new mining methods are developed. In addition to banning surface mining on Federal coal land with private ownership, the bill would severely hinder development on adjoining private and state lands because of the "checkerboard" nature of the Federal, state, and private mineral holdings and the difficulty in obtaining a coal resource block of minable size.

The following table, modified from data from the U.S. Geological Survey, summarizes estimated coal reserves under Federal lease.

Recoverable coal reserves held under Federal lease

State	Surface minable		Underground minable million tons	Total reserves million tons	Total acres leased
	acres	million tons			
Montana	21,777	1,120	0	1,120	36,232
N. Dak.	11,571	285	0	285	16,436
Wyoming	106,276	7,801	592	8,393	199,933
Total	139,629	9,206	592	9,798	252,601

Data on coalbed thicknesses and geographical extent are not sufficient to estimate coal resources-reserves on unleased Federal land, although the tonnages are believed to be much greater than on leased lands.

Reclamation Laws

Present reclamation laws enacted by states within the study area appear to offer little or no deterrent to increased coal production. However, should new or revised laws be enacted on either the Federal or state level requiring land restoration to the original contour, much of the strippable coal resource in the Northern Great Plains area could not be developed. Even when allowing for swell (volumetric expansion) of the overburden during the stripping phase of the mining operation, there will not be the necessary volume of overburden, in many areas, to return the land to the original contour after the thick coalbeds have been removed.

Conservation Laws

The present coal conservation law in Montana was enacted to insure full recovery of the coal resource from an area once mining has begun. Much of the coal is in multiple beds, and the law requires that a mining company recover all "strippable and marketable" coal. Under the law, the State Land Board will examine company cost records to determine if the coal is marketable. The coal companies are reluctant to give the State such information until the State guarantees the confidentiality of such information, an action the State has not yet taken.

Work Force

Preliminary data indicate that the work force for surface mining will not be a serious problem, at least through Development Plan II, Most Probable Forecast. Data are not available for an underground work force at this time, although it appears that there would be a shortage of underground workers if all surface mining were eliminated.

Increased Petroleum-Natural Gas Exploration, Production

Within the last year, the shortage of petroleum products in this country and the possibility of an increase in the wellhead price of natural gas have spurred petroleum exploration-production throughout the United States.

A significant amount of the Nation's domestic petroleum production comes from within the Northern Great Plains area. The amount and value of petroleum and natural gas production from the study area are discussed in the Petroleum review in the Noncoal Mineral Resource section.

At this writing, one of the effects of this country's support of Israel in the fourth Arab-Israeli conflict has been to point out the severity of the petroleum shortage when the Arab countries discontinue oil exports to the United States. A partial solution to the present shortage is to further increase petroleum exploration, both domestically and in countries friendly to the United States, and develop alternate energy sources such as oil shale and synthetic fuels from coal, garbage, etc., along with serious attempts to conserve petroleum consumption, either through voluntary or legislative action.

Much of the present petroleum production from the Northern Great Plains is from areas with thick coalbeds. An example is the Hilight field in Campbell County, Wyo. With increased exploration, other commercial oil and gas fields may be found in areas with significant coal reserves.

Other Minerals

Data indicate that the extraction of clay and uranium could conflict with the development of the coal resources in parts of the area. Investigation of individual sites will be necessary to delineate areas of potential conflict.

Coal Chemistry

The chemical composition of the Northern Great Plains coals could, under certain economic and technological conditions, act as a constraint to increased production.

1. Most of the coal in the Northern Great Plains is classified as low-sulfur coal, containing less than 1 percent sulfur, and is thus considered by many to be very attractive in view of Federal (EPA) regulations on sulfur dioxide emissions by power plants. This general belief is somewhat misleading, however, and could be significantly in error if even greater restraints on sulfur dioxide effluent are enacted. The point overlooked is that a 7,000-Btu subbituminous coal or lignite with 1 percent sulfur is no better than a 14,000-Btu bituminous coal with 2 percent sulfur; or, more realistically, a 7,000-Btu coal with 0.87 percent sulfur that has to be shipped 1,000 miles won't be able to compete with a washed 13,000-Btu coal with 1.5 percent sulfur that can be shipped from 150 miles away.

2. If efficient, practical, and economical sulfur-removal technology is developed in the next few years, the demand for coal from

the Northern Great Plains will lessen markedly, particularly in the Chicago and Detroit market areas.

3. The amount of alkaline constituents, particularly sodium, in some lignite creates a major problem in power plant boiler systems and makes lignite an inferior fuel.

4. Though not apparent now, the future environmental controls on deleterious elements such as selenium and fluorine may demote the value and demand of some coals from the Northern Great Plains.

Overburden Chemistry

If the mineral content of the overburden material will not allow successful reclamation, the area should not be mined by surface methods.

Mining Equipment

A crash program to develop the coal resources within the Northern Great Plains could be hindered by a shortage of mining equipment. Presently, there are three companies in the United States that manufacture stripping and reclamation equipment, shovels, and draglines with a cubic-yard capacity greater than 20. The total manufacturing capacity of these three companies is 16 machines a year. Sales personnel of one of these companies have stated that a dragline with a 36-cubic-yard capacity ordered in November 1973 could not be delivered before September - December 1975, and with a 6-month erection and checkout period would not be in operation before the summer of 1976. This is assuming that shortages of steel do not affect the production schedule.

It is expected that the 2-1/2-year lead time during normal conditions could be tripled or quadrupled under an extensive development program. Development of some strippable coal deposits could be curtailed or less efficient means of overburden removal might be necessitated. At present, an 18-month lead time exists for coal loading equipment.

Construction Materials

At present, there is a shortage of steel in the United States. This has affected the extractive mineral industry in the form of a shortage of roof bolts for mining and tubular steel for petroleum exploration. A shortage of structural steel would seriously hamper construction and the fabrication of coal cars, and gasification and electric generating plant equipment.

Mining Methods

Should legislative restrictions bar the surface mining of coal, increased production will be severely deterred. The near surface coalbeds in the study area cannot be mined from a safety, conservation, and economic basis by known underground mining methods. Dr. G. T. McBride, Jr., president of the Colorado School of Mines, has aptly stated the problem, "If the strata of earth and relatively weak and unconsolidated rock overlying the coal are thin enough to offer an economically feasible stripping ratio, then they are incompetent to be the roof of an underground mine." In a letter to the Colorado Congressional delegation, Dr. McBride added that underground methods of mining would require more miners and engineers than the industry could supply and that ". . . underground operations in thick seams, even where technically feasible, recover only one-fourth to one-third of the total coal and thus entail a severe sacrifice of our national resources."

Past underground coal mining in the study area has been by the room and pillar method. Entries are driven into the coal bed in multiple sets and right angle entries are developed from the main or initial entries. Coal is extracted from a series of "rooms" developed off of the secondary entries, leaving pillars of coal to help support the overlying strata. Coal recovery in beds less than 10 feet thick averaged 50 to 60 percent. However, in thick coalbeds, recovery can drop below 30 percent since the full coal thickness cannot be mined due to roof control and other problems.

There are numerous, documented cases of the environmentally devastating effects of past underground mining of near surface coalbeds in the study area. The surface has subsided over the old rooms, leaving a pock-marked surface unsafe and unfit for productive land use. There are reports of active subsidence today from mining operations 30 years ago. Subsidence has allowed air to reach the coal that could not be recovered and spontaneous combustion has occurred, consuming an unknown amount of coal and creating an air pollution and safety problem when the fumes from the burning coal reach the surface. It should be noted that no attempt was made to fill the voids left by coal extraction to attempt to lessen surface subsidence.

Unconsolidated-weakly consolidated conditions are present in the subsurface. Shale and siltstone are the predominant rock type and would offer serious problems in roof control, and therefore present hazards to men and equipment. Relatively thick, up to 20 feet, sandstones do occur, but are lenticular and would offer only local relief from the roof control problems.

Longwall mining, a method of coal recovery that allows the roof to subside after the coal has been extracted, has been used successfully in the Eastern United States and in a few areas of the West where conditions of deep, competent cover exist. "It is possible to cause the surface to subside more uniformly over longwall workings with consequently less surface building damage. In fact, many cities along the Ruhr have had vertical subsidence between 20 and 30 feet without serious damage." (Notes from course in Longwall Mining, Pennsylvania State University, 1972.) Special construction techniques are necessary to minimize subsidence damage.

Coalbeds in a thickness range of 38 to 84 inches are suitable for mining by the longwall method. Adverse mining conditions stated in the previously referenced course material are, "Roof and bottom extremes that make a seam unworkable are soft top or bottom or a too strong top that will not cave properly."

Possible problems with longwall mining in the study area are:

1. Environmental

a. Subsidence from mining would disrupt numerous aquifers and alter surface water drainage.

b. Subsidence could allow air to contact the near surface coalbeds, creating the possibility of spontaneous combustion.

2. Technological

a. Present mining machinery is limited to coalbeds less than 10 feet thick.

b. Machinery must be mobile; increasing size to mine thick beds, 30 to 60 feet, could create serious mobility problems.

c. Unconsolidated or weakly consolidated roof conditions could preclude longwall mining.

The constraints or deterrents to increased coal production in the Northern Great Plains Region as listed above are not intended to suggest conflict or confrontation. If solution of the energy problem and economic well-being are mutual objectives, and if delay is not introduced as a form of denial, then all areas of constraint or overlap of interest can be resolved by compromise, by a reordering of priorities, or by adjustment in laws and regulations.

NONCOAL MINERAL RESOURCES

Coal has been discussed rather extensively in preceding sections of this report. However, there are other mineral resources with varying degrees of importance in the Northern Great Plains Region. These economic minerals are discussed in the following sections. There are maps corresponding to the sections on petroleum, uranium, clay, and sand and gravel, as well as a map illustrating areas of potential mineral conflict.

Petroleum and Natural Gas

The oil and gas industry in the Northern Great Plains study area is located in part of four states, Montana, Wyoming, North Dakota, and South Dakota. Because of reporting methods, much of the information available deals with each individual state; therefore, data are presented for each state, and, where possible, data for the Northern Great Plains study area are tabulated. In North Dakota, all the oil and gas area lies within the Northern Great Plains study area. While it was necessary to use some 1971 data, generally the data represented are for the year 1972.

Locations of the 484 oil and/or gas fields in the Northern Great Plains area are shown on the oil and gas map (plate B-8) along with 11 refineries and 19 natural gas processing plants. In 1972, production from the four states was 194 million barrels of crude oil and 442 billion cubic feet of gas (table OG-1). Production from the Northern Great Plains area was 110 million barrels (table OG-2). (Note: North Dakota production from the study area was for 1971.) The crude oil was transported to various refineries (table OG-3), some of which were outside the study area, by pipeline and tank cars or trucks (table OG-4). The produced natural gas, 162 billion cubic feet, was distributed to consumers via pipeline after contained liquids were extracted by separators at the wellhead or at natural gas processing plants. Products manufactured from crude oil at refineries and products obtained from the natural gas processing plants are distributed by pipeline, rail-tank cars, and trucks to wholesale dealers. The three states of Montana, Wyoming, and North Dakota are all net exporters of petroleum products. For example, in 1971 Wyoming refineries produced over 23 million barrels of motor gasoline; less than 7 million barrels were consumed in the State. Wyoming was the only net exporter of natural gas with shipments totaling 243 billion cubic feet to Utah, Colorado, and Nebraska.

The 11 refineries located in the Northern Great Plains study area had a total through-put capacity of 258,780 barrels per calendar day

Table OG-1. - Petroleum and natural gas - 1972 data

Description	Montana	N. Dakota	S. Dakota	Wyoming
Number of refineries	8	2	0	9
Total capacity (1-1-73)(bbls per calendar day)	141,123	51,650	0	138,980
No. of natural gas processing plants	6	3	1	27
Capacity (million cu ft per day)	73.3	137.0	38.0	1,243.4
Area proved productive of oil and/or gas (acres)1/	220,000	192,000	4,000	620,000
Percent of total land area productive or leased1/	30.9%	45.7%	12.2%	57.4%
Employees engaged in oil and gas production1/	6,100	4,438	3,013	11,370
Rotary drilling rigs active in 1971 (av.)	17	9	None	45
Oil production (bbls)	33,900,000	20,624,000	220,000	140,011,000
Value	$102,378,000	$67,647,000	$570,000	$432,071,000
Average price per bbl	$3.02	$3.28	$2.59	$3.08
Number of producing oil wells1/	3,730	1,716	NA	9,250
Gas production (million cu ft)	34,900	32,000	0	375,059
Value	$4,117,000	$5,472,000	0	$60,760,000
Number of producing gas wells1/	525	32	NA	750
Oil reserves (thousand bbls)	228,185	174,011	NA	996,985
Gas reserves (million cu ft)	1,024,561	503,683	NA	4,131,492
Natural gas liquids (thousand bbls)	9,801	47,128	NA	97,642

1/ 1971 data.

Table OG-2 Oil and gas production, Northern Great Plains, 1963-1972
(oil, thousand barrels; gas, million cubic feet)

Counties	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Wyoming										
Campbell										
Oil	4,735	5,037	6,924	7,690	9,706	17,685	35,415	39,365	33,705	31,164
Gas	1,757	43	1,799	1,687	2,689	13,169	12,335	30,110	58,521	86,097
Fields	19	32	44	50	66	82	103	111	107	106
Converse										
Oil	4,171	4,622	5,343	5,614	5,596	5,162	4,596	5,004	4,526	4,338
Gas	744	1,916	2,182	2,329	1,674	1,428	1,138	949	1,805	1,497
Fields	8	9	8	10	12	13	15	18	17	19
Crook										
Oil	5,591	5,985	7,621	5,575	4,846	4,267	4,136	4,131	3,631	3,359
Gas	188	1,627	1,448	2,550	2,627	2,576	2,376	2,415	2,146	1,343
Fields	18	22	30	31	31	30	31	30	30	31
Johnson										
Oil	10,252	7,140	7,762	9,232	7,948	6,005	5,235	4,972	4,684	4,205
Gas	3,965	3,000	4,716	4,372	4,342	3,805	3,003	2,641	2,304	1,505
Fields	18	9	12	15	15	14	17	15	15	12
Natrona										
Oil	14,462	14,089	15,676	15,961	16,868	17,048	16,185	14,542	15,015	14,338
Gas	10,818	14,116	15,259	13,384	10,352	10,858	9,805	12,285	10,136	12,764
Fields	29	33	35	36	35	35	36	37	40	40
Niobrara										
Oil	781	931	1,016	898	760	646	595	514	504	450
Gas	541	174	549	645	586	559	473	368	240	854
Fields	6	13	13	13	11	13	11	11	14	12
Sheridan										
Oil	585	474	464	448	409	419	554	679	623	473
Gas	0	0	0	0	0	0	34	48	68	71
Fields	1	1	2	2	2	3	4	4	4	3
Weston										
Oil	6,708	5,089	5,169	3,929	3,405	4,369	4,328	4,626	4,912	5,604
Gas	994	321	1,282	1,073	1,080	945	793	317	784	581
Fields	10	15	17	18	18	16	18	19	22	26

Table 06-2 Oil and gas production, Northern Great Plains, 1963-1972--Continued
(oil, thousand barrels; gas, million cubic feet)

Counties	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Montana										
Big Horn										
Oil	82	116	128	156	169	136	122	96	98	80
Gas	49	47	40	41	43	36	31	29	30	21
Fields	4	5	5	5	5	5	5	4	5	5
Carter										
Oil	20	15	12	20	19	17	12	0	18	16
Gas	0	0	0	0	0	0	0	0	0	0
Fields	1	1	1	1	1	1	1	-	1	1
Daniels										
Oil	4	2	-1	0	77	23	0	0	0	0
Gas	0	0	0	0	0	0	0	0	0	0
Fields	1	1	1	-	1	1	-	-	-	-
Dawson										
Oil	1,723	1,513	1,254	1,219	1,129	1,021	891	757	723	718
Gas	0	0	0	0	0	0	0	0	0	0
Fields	6	7	7	6	6	6	6	4	6	7
Fallon										
Oil	8,707	8,370	7,819	7,567	8,315	7,962	7,367	7,658	7,011	6,825
Gas	5,835	4,911	4,394	4,823	6,673	8,231	9,607	8,417	9,966	14,040
Fields	10	11	11	11	13	13	13	13	13	13
Garfield										
Oil	234	240	195	179	191	197	178	174	196	195
Gas	0	0	0	0	0	0	0	0	0	0
Fields	1	1	1	1	1	1	1	1	1	1
Golden Valley										
Oil	0	0	0	0	0	0	0	0	0	0
Gas	958	1,013	1,018	987	988	1,059	1,039	997	1,110	1,216
Fields	1	1	1	1	1	1	1	1	1	1
McCone										
Oil	162	277	1,271	2,261	1,658	945	589	364	269	521
Gas	0	0	0	0	0	0	0	0	0	0
Fields	2	3	4	4	4	4	5	2	6	6

Table OG-2 Oil and gas production, Northern Great Plains, 1963-1972--Continued
(oil, thousand barrels; gas, million cubic feet)

Counties	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Montana (Con.)										
Musselshell										
Oil	1,200	1,094	1,069	995	1,215	1,318	835	665	760	1,163
Gas	0	0	0	0	0	0	0	0	0	0
Fields	8	11	12	13	14	14	14	9	15	15
Powder River										
Oil	0	0	9	70	1,671	16,572	13,297	7,826	5,961	6,332
Gas	0	0	0	0	0	586	9,177	6,905	2,702	838
Fields	-	-	1	2	1	1	3	2	3	3
Richland										
Oil	205	174	171	288	407	1,264	2,002	1,833	1,611	1,632
Gas	0	0	0	0	0	0	0	0	0	0
Fields	2	2	3	3	4	6	10	12	13	14
Roosevelt										
Oil	2,615	2,292	2,540	2,454	2,216	2,019	2,020	1,811	2,209	1,343
Gas	0	0	0	0	0	0	0	0	0	0
Fields	5	10	11	11	12	12	15	14	17	17
Rosebud										
Oil	2,326	1,732	1,390	1,213	1,086	894	845	873	1,237	1,412
Gas	0	0	0	0	0	0	0	0	0	0
Fields	5	5	4	4	4	5	5	2	4	3
Sheridan										
Oil	1,336	1,470	2,227	3,006	2,859	2,550	2,363	2,550	2,599	2,479
Gas	0	0	0	0	0	0	0	0	0	0
Fields	6	7	7	10	11	11	12	13	14	18
Valley										
Oil	0	0	0	0	0	0	0	0	0	0
Gas	1,994	2,021	2,189	2,148	2,072	1,989	1,948	2,637	2,395	2,624
Fields	1	1	1	1	1	1	1	1	1	1
Yellowstone										
Oil	202	211	205	366	389	226	160	104	88	53
Gas	0	0	0	0	0	0	0	0	0	0
Fields	2	2	2	3	3	3	3	2	3	3

Table OG-2 Oil and gas production, Northern Great Plains, 1963-1972--Continued
(oil, thousand barrels; gas, million cubic feet)

Counties	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Montana (Con.)										
Wibaux										
Oil	4,191	3,860	4,010	4,046	3,937	3,824	3,551	3,312	3,029	2,827
Gas	699	699	736	778	820	841	731	669	600	503
Fields	1	1	1	1	1	1	1	1	1	1
North Dakota										
Billings										
Oil	1,018	746	1,252	2,179	2,363	2,292	2,073	1,869	1,812	
Gas	591	404	527	781	1,359	1,759	1,835	1,154	1,266	
Fields	6	8	6	6	6	6	6	6	6	
Bowman										
Oil	1,016	789	716	753	711	643	641	749	933	
Gas	602	604	338	445	532	300	237	314	1,632	
Fields	4	4	4	5	5	6	7	6	6	
Bottineau										
Oil	3,560	3,750	3,396	3,274	2,982	2,921	3,162	2,280	3,283	
Gas	307	881	376	386	392	340	430	409	420	
Fields	23	26	27	23	23	25	26	25	28	
Burke										
Oil	3,587	3,584	3,530	3,140	2,799	2,509	2,066	1,951	1,877	
Gas	9,277	7,071	7,905	7,658	7,571	7,143	6,265	5,098	4,264	
Fields	18	18	18	18	17	16	16	15	14	
Divide										
Oil	194	181	148	172	172	178	165	175	153	
Gas	197	193	145	167	127	170	477	232	195	
Fields	4	4	5	5	5	6	6	5	5	
Dunn										
Oil	30	28	24	32	24	18	18	12	15	
Gas	12	0	0	15	15	7	3	2	3	
Fields	1	1	1	1	1	1	1	1	1	

Table OG-2 Oil and gas production, Northern Great Plains, 1963-1972--Continued
(oil, thousand barrels; gas, million cubic feet)

Counties	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
North Dakota (Con.)										
Golden Valley										
Oil	0	0	0	0	0	0	39	58	64	
Gas	0	0	0	0	0	0	3	6	6	
Fields	-	-	-	-	-	-	1	1	2	
McHenry										
Oil	48	56	55	43	41	32	25	21	17	
Gas	4	0	5	4	2	2	2	1	2	
Fields	1	1	1	1	1	1	1	1	1	
McKenzie										
Oil	6,678	4,805	7,490	7,474	6,375	5,901	4,617	4,355	4,268	
Gas	8,184	5,310	11,932	15,504	18,268	18,348	14,388	10,799	10,132	
Fields	21	19	23	23	22	22	22	22	20	
Mountrail										
Oil	150	145	136	130	104	95	86	77	68	
Gas	112	121	115	118	136	163	101	72	66	
Fields	2	2	2	2	2	2	2	2	2	
Renville										
Oil	803	1,348	1,808	1,634	1,562	1,466	1,288	1,201	1,227	
Gas	220	434	500	478	448	437	376	297	286	
Fields	4	7	6	9	9	9	9	11	12	
Stark										
Oil	35	52	104	180	1,124	1,490	1,518	1,739	1,713	
Gas	2	0	5	127	369	527	613	928	907	
Fields	1	1	1	4	4	5	5	5	5	
Ward										
Oil	11	0	7	5	37	215	371	359	662	
Gas	3	0	-1	1	9	60	70	74	139	
Fields	1		1	1	2	2	1	2	2	
Williams										
Oil	8,396	8,408	7,612	8,141	7,058	7,213	6,685	5,892	5,506	
Gas	15,570	20,698	20,752	21,010	18,714	17,491	16,005	15,691	19,139	
Fields	14	14	14	14	17	20	19	17	20	

Table OG-2 Oil and gas production, Northern Great Plains, 1963-1972--Continued
(oil, thousand barrels; gas, million cubic feet)

Counties	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
South Dakota										
Harding										
Oil	0	196	190	220	194	174	150	154	224	213
Gas	0	0	14	14	0	11	9	10	9	8
Fields	-	2	2	2	2	2	2	2	2	2

(table OG-1). Crude oil supplies for these refineries came from fields within and outside of the study area plus imports from Canada (table OG-3). Locations of the individual refineries are shown on the map, and capacity data are in table OG-5.

The 19 natural gas processing plants are located on the map and in table OG-6. Products derived from natural gas processing plants include ethane, liquefied petroleum gases, gasolines (including natural, motor, and aviation), naphtha, jet fuel, kerosine, distillates, and other products. The most important products are liquefied petroleum gases and natural gasoline; these two constitute over 75 percent of the production. Natural gas liquids output from processing plants is principally for refinery blending stock.

Within the study area, reservoirs which contain hydrocarbons range in geologic age from Tertiary to Ordovician with the younger and older producing strata in North Dakota. In both Wyoming and North Dakota, production has been found at relatively shallow depths. In the North Tisdale field, Wyo., production was found at 150 feet below the surface; in the Maxbass field, N. Dak., natural gas was discovered at 180 feet; and in the Cedar Creek field, Mont., natural gas was discovered at 600 feet. The deepest production comes from the Pheasant field, Johnson County, Wyo., at 14,990 feet. The Alexander field in North Dakota produces from the Red River formation at 13,543 feet. Potential new oil and gas fields are present throughout the Northern Great Plains study area, but it is impossible to predict the location of these new discoveries. The large percentage of land currently leased (table OG-1) for oil and gas drilling is indicative of the expectations of

Table OG-3. - Refinery receipts of crude oil by state, 1971
(thousand barrels)

State	Intrastate receipts	Interstate receipts	Imports	Total
Montana	11,972	14,784[1]	14,767	41,523
North Dakota	16,204	1,086[2]	758	18,048
South Dakota	No refineries - Production goes interstate			
Wyoming	46,691	907[3]	1,197	48,795

[1] All from Wyoming.
[2] All from Montana.
[3] Nebraska, North Dakota, and South Dakota, 2; Colorado, 800; Montana, 105.

Table OG-4. - Refinery receipts of crude oil by state and method of transportation, 1971
(thousand barrels)

State	Intrastate		Interstate		Total
	Pipeline	Tank cars & trucks	Pipeline	Tank cars & trucks	
Montana	11,109	863	29,551	0	41,523
North Dakota	16,203	1	1,843	1	18,048
Wyoming	45,803	888	2,003	101	48,795

Table OG-5. - Refineries in Northern Great Plains area, 1972

Company	Location	County	Capacity bcd
	Montana		
Continental Oil Co.	Billings	Yellowstone	47,000
Exxon U.S.A.	Billings	Yellowstone	45,000
Farmers Union	Laurel	Yellowstone	31,500
Spruce Oil Co.	Wolf Point	Roosevelt	2,500
Jet Fuel	Mosby	Garfield	450
Total			126,450
	North Dakota		
American Oil	Mandan	Morton	48,000
Westland Oil	Williston	Williams	3,650
Total			51,650
	South Dakota		
None			
	Wyoming		
American Oil	Casper	Natrona	37,000
Texaco	Casper	Natrona	22,000
Little America Refining	Casper	Natrona	13,500
Tesoro Petroleum	Newcastle	Weston	8,180
Total			80,680

Table OG-6. - Natural gas processing plants in Northern Great Plains area, 1972

Company	Plant	County
	Montana	
McCulloch Gas Proc. Corp.	Tule Creek Gas	Roosevelt
McCulloch Gas Proc. Corp.	Fairview Field Gas	Richland
	North Dakota	
Texaco	Lignite Plant	Burke
Hunt Industries	North Tioga Plant	Williams
Signal Oil and Gas Co.	Tioga Plant	Williams
	South Dakota	
McCulloch Gas Proc. Corp.	Belle Fourche	Butte
	Wyoming	
Apache Gas Production	Recluse	Campbell
Atlantic Richfield	Gillette	Campbell
Continental Oil	Sussex Plant	Johnson
Ginther N C Gas Co.	Rozet	Campbell
Ginther N C Gas Co.	Springen	Campbell
Kan-Neb Nat. Gas Co., Inc.	Casper Gasoline	Natrona
Kan-Neb Nat. Gas Co., Inc.	Flat Top	Converse
McCulloch Gas Proc. Corp.	Gas Draw	Campbell
McCulloch Gas Proc. Corp.	Highlight Gas	Campbell
McCulloch Gas Proc. Corp.	Jamison Prong	Campbell
McCulloch Gas Proc. Corp.	Oedekoven	Campbell
McCulloch Gas Proc. Corp.	Ute Gas	Campbell
McCulloch Interstate Gas	Rocky Point Gas	Campbell
Phillips Petroleum Co.	Douglas	Converse

the industry to find new reserves of oil and gas. Increased prices for crude oil and natural gas will accelerate drilling activity to discover new reserves.

Inputs and products manufactured were summarized from MERITS (Bureau of Mines Energy Resources, Information, and Transportation System) for the refineries and natural gas processing plants.

Uranium

Uranium is the basic raw material of the atomic age. First used in a military weapon in World War II, uranium now is being used mostly as an energy source to generate electric power. The outlook is bright for future use of uranium for producing electricity. Whether the supply will be adequate to furnish enough uranium to meet these projected needs is still very much in doubt. The development of a breeder-reactor, which the government is presently trying to develop, would require less uranium supply because such a reactor would be able to produce uranium fuel as it is being operated.

A typical light-water reactor of 1,000 megawatts electric capacity needs enriched uranium produced from 550 to 625 tons of U_3O_8 for the initial loading and about 200 tons of U_3O_8 per year for refueling. Recycling of plutonium from the spent reactor fuel elements could reduce annual makeup requirements to about 170 tons of U_3O_8. Power plants normally have an operating life of 30 years or more. Based on this information, a 1,000 megawatt nuclear power plant operating for 30 years would use 5,700 tons of U_3O_8.

Other applications include the use of uranium in the form of uranium oxides by the chemical industry and in the form of radiostopes in the fields of medicine, agriculture, industrial gases, space, and other industries. Although presently not of commercial importance, the use of uranium in industrial explosives for mining, excavation, natural gas production, and desalting sea water could utilize substantial quantities of uranium.

Known deposits and occurrences of uranium are not widely distributed in the Northern Great Plain area. Plate B-9 shows the location of major and minor uranium districts and scattered deposits and occurrences outside these districts. Individual deposits and occurrences were usually too numerous to show within the district. Most of the deposits and occurrences are in Wyoming.

As of January 1, 1973, the uranium ore reserves and potential resources of the United States, based on a value for a pound of U_3O_8 at \$8 or less, were 273,000 tons and 450,000 tons U_3O_8, respectively. The Northern Great Plains contains 43,500 tons U_3O_8 or 16 percent of the U.S. reserves, and 36,000 tons or 8 percent of the U.S. potential resources.

All ore reserve and potential resource estimates were determined by the U.S. Atomic Energy Commission (AEC). The term ore reserves refers to the quantity of uranium in known deposits which can be economically produced within the stated cost (\$8 or less per pound U_3O_8). The quantity, grade, and physical characteristics have been established with reasonable certainty by detailed sampling, initially by surface drilling and later supplemented by underground drilling and sampling. The density and method of sampling are determined by the size, depth, and geologic features of the deposit.

Potential resources are estimates of the quantity of uranium in addition to reserves that may exist in unexplored extensions of known deposits or in undiscovered deposits within or near known uranium areas. The estimates are based on extrapolations from explored to unexplored or incompletely studied areas applying favorability factors based on geologic evaluations.

In determining ore reserves and potential resources at a given value per pound of U_3O_8, the AEC only considered the cost of mining, haulage, royalty, and milling costs. Property acquisition costs, finding costs, cost of money, money accumulation for the replacing of the ore reserve, and a profit were not used by the AEC in determining an ore reserve. However, these costs must be considered by each company and integrated into their negotiated selling price.

The most important locality in the Northern Great Plains for uranium is the Powder River District which is in the southern part of the Powder River Basin. This district contains 92 percent of the ore reserves and 72 percent of the potential resources. The ore reserves for the district are 25,400,000 tons of ore containing 40,000 tons U_3O_8 and the potential resources, 14,000,000 tons of ore containing 26,000 tons U_3O_8.

Uranium was first discovered in the Powder River District in 1951 by J. D. Love of the U.S. Geological Survey near the Pumpkin Buttes in the northern part of the district. Later in 1952, the Pumpkin Buttes were withdrawn from mineral entry while the Geological

Survey investigated the area for uranium. On November 17, 1955, the area was restored to mineral entry and immediately considerable staking and overstaking of mining claims took place. In the late 1950's, exploration, development, and mining took place in the Pumpkin Buttes and other localities in the district such as Turnercrest, Monument Hill, and Box Creek. However, this work was only conducted for shallow deposits at or near the surface.

Exploration activity for uranium in the Western United States was accelerated greatly in the late 1960's after the AEC announced that known supplies were not sufficient to meet projected demands of uranium for proposed and future nuclear powered generating plants. One of the places that was subjected to considerable exploration work was the Powder River District. This work resulted in the discovery of significant deposits which contain the present ore reserves. Two of these deposits are now being mined, and another is under development.

Currently, there are four uranium mining operations and two milling operations active in the Northern Great Plains; all are located in Wyoming. Three of the mining operations are open pits, of which two are in the Powder River District and one in the Gas Hills District. The fourth operation is an underground mine being developed in the Powder River District. One of the uranium mills is in the Powder River District and the other in the Gas Hills District. The location of the mines and mills are shown in plate B-9.

Exxon Corp. (formerly Humble Oil and Refining Co.) is operating the Highland open pit and mill in the Powder River District. Stripping of overburden began in 1970 and initial mine production in July 1972.

Construction of the 2,000 ton-per-day mill began in 1971, and initial mill production was started in October 1972. During 1972, 256,152 tons of ore were mined and 92,345 tons milled. Twenty-nine million yards of overburden have been removed up to September 1973. Mullen Mining does the primary overburden removal and Russell Forgey Construction Co., the internal mine waste removal. Mining and milling of the ore is done by Exxon. According to an article on page 5 of the June 14, 1973, issue of the Riverton (Wyo.) Ranger newspaper, Exxon had 117 employees; Mullen Mining, 72; and Forgey, 24. According to the AEC's final environmental statement (Docket No. 40-8102, dated March 1973) related to the operation of Exxon's Highland uranium mill, approximately 600 acres of land (including 250 acres as waste dumps) and 120 million cubic yards of earth will be disturbed during the open pit phase. Approximately 280 acres of land will be disturbed by the milling activities during the life of the project. The mill will occupy about 30 acres and the tailings or mill waste area about 250 acres.

Upon completion of all ore extraction that can be removed by open pit, the company will remove ore by underground methods starting in the wall face of the pit. On July 26, 1973, Exxon announced plans to develop two underground mines from a common 670-foot, 14-foot diameter shaft located about 1-1/2 miles north of the mill. A contract to sink the shaft has been let. Fifty contract miners are expected to be used in the sinking operation, and an additional 100 men will be used to mine the ore. Production from these mines is expected about January 1977.

The other producing open pit in the Powder River District is the Morton Ranch mine of Teton Exploration Drilling Co., Inc. The mine first attained production in September 1973. Ore from the pit is sold as custom ore to Exxon who in turn processes it at their Highland uranium mill. The ore from the pit is trucked to the mill which is only about 6 miles from the pit. At this time there are no operational data available.

About 2 miles southwest of Exxon's operation, Kerr-McGee Corp. is having a 16-foot diameter shaft sunk 950 feet deep as part of developing the Bill Smith underground mine. The shaft sinking is being done by Mine Contractors, Inc., a wholly-owned subsidiary of Kerr-McGee. Thirty-five men were employed as of June 1973 in this work. The shaft is being sunk by conventional methods using a Cryderman mucker. After completion, three compartments, two for hoisting ore and one for men and materials, will be installed. The shaft is expected to be completed early in 1974 and production attained later in the year. In a press release dated February 1, 1973, the president of Kerr-McGee stated, "Operations are now in progress to sink the company's first uranium shaft in the Powder River Basin area of Wyoming. The project, when completed, will include one or more additional shaft mines and one or more open pits, as well as a mill."

Another major uranium district is the Gas Hills in central Wyoming. Only the far eastern end of this district is in the Northern Great Plains. Union Carbide Corp. operates an open pit and mill in the part of the Gas Hills in the Northern Great Plains. In 1972, 231,997 tons of ore was mined from this pit. They also operate a smaller open pit which is near the mill but outside of the Northern Great Plains area. The mill is rated at 1,000 tons per day. According to the 1972 annual report of the Wyoming State Mine Inspector, 84 people were employed by Union Carbide at their operation in Natrona County

Outside the two major districts there are a few places that have some significant uranium mining activity but have ceased being uranium producing areas. One of these places is the uraniferous lignite area in the northwest part of South Dakota, southwest part of North Dakota, and southeast part of Montana. Most of the uraniferous lignite production came from the Little Missouri District in North Dakota and the Cave Hills and Slim Buttes in South Dakota.

Radioactive lignite in the Northern Great Plains was first detected by D. G. Bryant and E. P. Beroni of the U.S. Geological Survey in 1948 in western North Dakota. In the early 1950's, the Survey and Bureau of Mines did some exploration work for the AEC. Production was first attained in 1955 and up to 1958 was limited to numerous small shipments from scattered prospects in North and South Dakota. During this time the uraniferous lignite was not amenable to the conventional uranium milling processes. Considerable research on treating such material was conducted between 1955 and 1957. Little or no activity of mining uraniferous lignite took place until 1962. The mid-1960's was the period of greatest mining activity; at one time, three companies operated kilns. The practice at that time was to mine the uraniferous lignite, then burn it in kilns, and ship the ash to uranium mills for recovery of the uranium. At some mines the lignite was uncovered and burned in place and the ash picked up and shipped to a mill. Some molybdenum was obtained from the ash as a byproduct during milling operations. Currently, the AEC reports a reserve figure for uraniferous lignite deposits in North Dakota and South Dakota of 118,000 tons of ore containing 400 tons U_3O_8 based on a value of $8 per pound U_3O_8 and has no potential resources.

A locality in the lignite area that has recently had some exploration activity is Carter County, Mont. However, this work is not to locate uraniferous lignite deposits but rather uranium deposits at depth in the Inyan Kara formation. This formation is the host rock of many commercial uranium deposits in the southern Black Hills District in Harding and Pennington Counties in South Dakota.

Another place in the Northern Great Plains that had some significant uranium production is the Northern Black Hills District in northeastern Wyoming. Uranium was first discovered in this area in 1952 near Carlile, Wyo. Production was attained the next year and continued until 1967. Some vanadium was recovered as a byproduct from uranium ores mined in this district. In the past few years, the district has been explored but so far no large discoveries have been announced. The largest single operation in the district was the Hauber mine in northeastern Crook County. Homestake Mining Co. acquired the property in 1957 and mined until August 1967. According to company annual reports, about 600,000 tons of ore was mined.

The total uranium production for the Northern Great Plains is shown in table 25.

Table 25. - Uranium production in the Northern Great Plains

State and production period[1]	Ore			Recoverable U_3O_8	
	Tons	U_3O_8 content Pounds	Value[2]	Pounds[3]	Value[4]
Montana[5]					
1955	[6]			[6]	
N. Dakota[7]					
1954-1968[8]	83,011	581,755	$ 2,506,185	529,599	$ 4,243,869
S. Dakota[9]					
1954-1966[10]	52,190	440,533	1,947,083	417,113	3,382,467
Wyoming[11]					
1950-1972[12]	2,876,185	8,693,392	28,142,021	8,000,618	64,088,022
Total	3,011,386	9,715,680	$32,595,289	8,947,330	$71,714,358

[1] Production may have not been continuous during the reported period.
[2] F.o.b. mine.
[3] Estimated based on mill recovery factors.
[4] Estimated based on average price per pound U_3O_8.
[5] From Fallon County.
[6] Very minor production.
[7] From Billings, Slope, and Stark Counties.
[8] No production reported 1957-1961.
[9] From Butte and Harding Counties.
[10] No production in 1959, 1961, 1962, and 1964.
[11] From Campbell, Converse, Crook, Johnson, Natrona, Niobrara, and Weston Counties.
[12] No production in 1952.

Uranium is only mined and milled in the Northern Great Plains. The uranium concentrates from the milling operations are sent out of the region for further processing, mostly into fuel elements for use in nuclear power electrical generating plants.

Reynolds Metals Co. announced in September 1973 that they had been unsuccessful in forming a uranium reduction group of companies to build and operate a $2.2 billion uranium enrichment plant near Buffalo. Wyo.

The cost of mining uranium ore depends largely on the size, shape, and location of the orebody, and the rate of production. Van Alstine and Curry of the AEC in an article on mining in Wyoming discussed the methods and costs of mining. They stated that open pit mining has several definite advantages over underground mining when it can be employed. Advantages of open pit mining are: overall lower costs, multiple ore horizons can be mined more easily, all or most of the ore can be removed, and lower grade material can be mined. The depth of the orebody is the main limiting factor to an open pit. As depths increase, the waste to ore ratio quickly becomes excessive so that economics dictate that underground mining methods are used. Most underground mines anticipated in Wyoming will require shaft entry, although some ore will continue to be mined from pit-wall adits. A limited market may favor underground mining because of the resultant slow return of the high initial cost of stripping a pit, compared with the substantial lower cost of sinking a shaft. The main disadvantage to open pit mining is that large parcels of land are disturbed. The surface of the land and the waste material (overburden) over the ore must be removed and placed in piles and a large hole is left in the ground. In some cases, partial back filling of a pit may be possible.

Tables 26 and 27 are mining costs that can be encountered in open pit and underground mine operations, respectively, as set forth by Van Alstine and Curry.

In situ leaching of uranium deposits and leaching of underground mine-workings have been tried either on an experimental or limited basis but are not presently competitive on a large scale with conventional mining methods. However, this may change with improvement in technology.

Table 26. - Open pit mining costs, 1970

Stripping	Range	Average
Equipment	$0.03 to $0.06/yd	$0.05/yd
Operating	$0.17 to $0.30/yd	$0.22/yd
Total	$0.20 to $0.36/yd	$0.27/yd

Mining*	Range	Average
Operating	$1.50 to $3.00/ton	$2.50/ton

*Mining costs include labor, supplies, maintenance, supervision, insurance, taxes such as production taxes and payroll taxes, and administrative charges at the mine. Haulage costs of approximately $0.04 per ton mile from mine stockpiles to the mill, and offsite charges are not included.

Table 27. - Underground mining costs, 1970

Range	Range	Average
Surface plant	$150,000-$800,000	$600,000
Equipment	$0.20 to $0.40/ton	$0.25/ton
Shafts		
Rectangular	$300 to $700/ft	$500/ft
Circular concrete	$500 to $800/ft	$700/ft
Drilled	$720 to $950	
Shaft stations		$0.55/cu yd
Drifting (Tracked)		
Wet	$50 to $90/ft	$60/ft
Dry	$40 to $60/ft	$50/ft
Raising	$30 to $60/ft	
Operating*		
Dry room and pillar (on level)	$4.50 to $7.00/ton	$6.00/ton
Wet room and pillar (sub-ore haulage)	$7.50 to $13.00/ton	$9.50/ton
Long wall retreat	$8.00 to $13.00/ton	$11.00/ton

*Operating costs include labor, supplies, maintenance, supervision, engineering, insurance, taxes, and administrative charges at the mine.

Uranium milling costs depend on the type and grade of ore handled, the process used, and the size of the mill. The AEC has published some typical operating costs for uranium mills. Based on processing 0.25 percent U_3O_8 ore, a 95 percent recovery, and a 75 percent U_3O_8

concentrate, the total operating costs per ton of ore for a 200-tpd, 400-tpd, and 1,000-tpd mill was $9.75, $6.94, and $5.72, respectively. Included in the cost were labor, supplies, utilities, taxes, insurance, travel, and other miscellaneous expenses. The total construction cost was estimated to be $2 million for the 200-tpd mill, $3.1 million for the 400-tpd mill, and $5.9 million for the 1,000-tpd mill. Based on a 10-year period, the mill amortization cost per ton of ore was $2.78, $2.15, and $1.64, respectively.

Table 28 shows a range and average of cost items for producing a uranium concentrate from a mining and milling operation.

Table 28. - Uranium production cost, 1969

	Cost per pound U_3O_8 recovered	
	Range	Average
Land or royalty	$0.30 - 0.50	$0.40
Exploration	.60 - 1.00	.80
Development and mining	1.95 - 2.45	2.20
Milling	.75 - 1.25	1.00
Administration	.10 - .30	.20
Amortization	.75 - 1.25	1.00
Total	$4.45 - 6.75	$5.60

Source: Data furnished by the BuMines to Cameron Engineers.

Mined ore is trucked from the mine to the mill. The distance could be from less than a mile to more than a hundred miles, depending on the locations of the mines and mills. In a few instances, trucks have hauled the ore to a railhead and then shipped to a mill on a railroad. The two mills in operation in the region are not on railroads. Exxon's mill is about 15 miles from a railroad and Union Carbide's mill about 30 miles.

Concentrates of U_3O_8 from the milling operation are placed in 55-gallon drums and transported by truck to the refinery.

The AEC publishes employment information of exploration, mining, and milling activity in their annual publication, "Statistical Data of the Uranium Industry." This report is published by the Grand Junction (Colo.) office of the AEC. According to the latest report (January 1, 1973), there were 1,199 people employed in mining in Wyoming, 179 people in milling in Wyoming and South Dakota, and 441 people in exploration in Wyoming, South Dakota, North Dakota, and eastern Montana. No detail breakdown was given so it could be determined how many of these people are employed within the Northern Great Plains Region.

As previously discussed, there are three producing open pits and two uranium mills in operation and one underground mine under development in the Northern Great Plains Region. Some plans have already been made by companies to develop more open pits and underground mines and another uranium mill in the Powder River District. This district is the only one in the region expected to see increasing uranium mining and milling activity in the near future. Table 29 shows the expected rate of ore production for the period 1973-1985. Based on the projection it can be expected that at least four uranium mills will have to be in operation in the Powder River District to take care of the anticipated ore production.

Geothermal Resources

Areas within the Northern Great Plains Resource area that are thought to have geothermal potential are few. A total of three areas, two in Natrona County and one in Converse County, Wyo., are the only ones known at this time. None has been explored. Two other areas, one in Phillips County, Mont., and one in Fall River County, S. Dak.,

Table 29. - Projection of uranium ore production in Northern Great Plains, 1973-1985
(millions of tons of ore)

Wyoming Counties		1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Campbell	High	0	0	0	0	0	.4	.8	1.1	1.1	1.1	1.1	1.1	1.1
	Low	0	0	0	0	0	.2	.6	.9	.9	.9	.9	.9	.9
Converse	High	.870	.890	.890	.890	1.20	1.70	2.40	3.2	3.2	3.4	3.4	3.4	3.4
	Low	.850	.860	.860	.860	1.00	1.40	2.00	2.8	2.8	3.0	3.0	3.0	3.0
Johnson	High				.440	.440	.80	.80	.80	.80	.80	.80	.80	.80
	Low				.420	.420	.70	.70	.70	.70	.70	.70	.70	.70
Natrona	High	.250	.250	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25	.25
	Low	.200	.200	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20	.20
Total	High	1.12	1.14	1.14	1.58	1.89	3.15	4.25	5.35	5.35	5.55	5.55	5.55	5.55
	Low	1.05	1.06	1.06	1.48	1.62	2.50	3.50	4.60	4.60	4.80	4.80	4.80	4.80

Source: Wyoming Department of Economic Planning & Development.

are both outside the study area. Other areas in Montana and Wyoming are also outside the area.

Possibilities for developing geothermal power in the study area are remote. Neither Wyoming nor the Federal Government has, at this time, leased any land for exploration; there are major legal problems associated with geothermal development that must await court decisions; and more than 5 years are required to develop a geothermal field. Other problems consist of possible subsidence problems, the plant must be located at the steam source, and geothermal wells have a lifespan of only 50 to 60 years.

These things added together with the development of power from coal, the lack of technical knowledge about geothermal development, and sparseness of known geothermal anomalies in the study area indicate that geothermal power plants will probably not be developed in the Northern Great Plains Resource area in the foreseeable future.

Not enough is known about the geothermal anomalies in the area to speculate on the potential for development.

Clay

Clays, predominately fine-grained hydrous aluminum silicates, occur througnout the study area. The clay materials are formed by the weathering and alteration of preexisting rock materials, hydrothermal alteration, or in some cases by diagentic processes. During the formation of clays, the soluble constituents of the original rocks are leached out, leaving behind the relatively stable aluminum silicates that are reformed as clay minerals.

Clays occurring in the Northern Great Plains Resource Program area are divisible into the following categories: bentonite, fire and common or miscellaneous, and shale.

Bentonite, a clay composed chiefly of the mineral montmorillonite, is used in drilling muds, metallurgical moulding sand, and for the binding material used in pelletizing taconite iron ore, animal feed binder, and hundreds of other uses to a smaller degree. Significant tonnages are used to line canals and ponds to prevent seepage.

Both swelling and nonswelling bentonite occur in the study area. The swelling bentonite is useful in drilling mud, as a bonding material, and as a pelletizing medium. The nonswelling variety is used as a petroleum catalyst. Both types of bentonite are an alteration product of volcanic ash. Wyoming supplies 70 percent of the bentonite used in the United States; and Wyoming, Montana, and South Dakota are the only states producing swelling bentonite.

Bentonite is found in the lower part of the Pierre Shale and in the upper part of the Belle Fourche and Mowry Shales in Wyoming and Montana. Bentonite is also widespread in the Bear Paw Shale in Montana. The bentonite in South Dakota is in the Belle Fourche formation. All of these beds are of the Upper Cretaceous age.

The following section on processing and mining is taken from a paper by T. E. Wayland given at the AIME Annual Meeting in Denver, Colo., February 1970.

"Mining and Processing--Conventional surface mining methods predominate in the bentonite mining industry; underground methods are used to mine small deposits in California which are capped by basalt. In most bentonite deposits, a common practice is to strip the overburden and expose the clay to the atmosphere for several months. This aging process, accelerated by ripping or plowing the bed, has been found to improve the quality and promote natural drying. While the bed is exposed, detail quality data can be determined by closely spaced sampling and testing; these data enable the miner to remove similar quality materials selectively.

"Bentonite is loaded on large trucks with capacities up to 50 cubic yards for hauling to the processing plant. At the plant, bentonite is weighed and stockpiled according to quality; this arrangement offers the advantages of all-weather processing, moisture evaporation, quality enhancement by oxidation, and the opportunity to produce desired products by blending.

"The milling process consists of crushing (or slicing), drying, and fine grinding. Most producers use conventional clay slicers and rotary dryers; some of the newer plants, however, now utilize hammer mills and fluid-bed dryers. Roller mills are standard equipment for grinding. Quality control of shipments is maintained by laboratory tests; moisture content, including laboratory humidity, is critical."

The product is fed mechanically to packing machines which fill 4-ply paper bags of 100 pounds capacity for shipment to many parts of the United States and to other countries.

The economics of bentonite production closely follows that of other nonmetallic mineral deposits. Because of the low value of the product, it is necessary that plants be located near railroads or navigable waterways and centrally located near the reserves.

In Montana within the study area, bentonite has been mined intermittently from several deposits. Bentonite occurrences have been reported from Valley, Garfield, Carter, Roosevelt, McCone, Rosebud, Treasure, Musselshell, Golden Valley, Big Horn, and Yellowstone Counties. Within this area, three bentonite mines are presently in operation; one each in Carter, Rosebud, and Treasure Counties. Two in Valley County are in the development stage. Active mines presently employ 64 people.

In South Dakota, Butte County is the only county lying within the study area that contains significant resources of bentonite. Data on resources, quality, and quantity are presented in U.S. Geological Survey Bulletin 1082-M. One company, The American Colloid Company, is mining and processing bentonite in Butte County.

Wyoming bentonite production within the study area came from Crook, Campbell, Weston, and Natrona Counties. In 1971, four companies produced bentonite from six mines in the area.

Fire clay, a material which contains low percentages of iron oxide, lime, magnesia, and alkalies can withstand temperatures of 1,500° C or higher allowing the finished product to be used as a refractory. Although deposits of fire clay occur within the Northern Great Plains area, there were no reports of mining in 1971.

Common or miscellaneous clay is a material which is sufficiently plastic to permit moulding and vitrification below 1,100° C, and shale is essentially an indurated or hardened form of common clay. Both materials are used in the manufacture of structural clay products such as brick, drain tile, and lightweight aggregate. In 1971, common clay and shale were mined from the study area in Montana, North Dakota, and South Dakota.

Fire and common clay and shale are mined by surface methods using equipment such as draglines, power shovels, scraper-loaders, and shale planers. Recovery approaches 100 percent of the minable clay beds.

Processing of fire clay generally consists of crushing, calcining, and blending while the processing steps for common clay and shale are crushing, blunging, extruding, and drying.

Clay production (millions of short tons) and value (millions of dollars) in the Northern Great Plains area are summarized below.

State	1970		1971		1972	
	Production	Value	Production	Value	Production	Value
Dakotas	0.110	0.911	0.198	1.973	0.180	1.866
Montana	.144	.694	.219	1.537	.234	1.379
Wyoming	1.246	12.888	1.108	11.263	1.177	12.026

The U.S. Bureau of Mines has forecast the national demand for the individual clay types for the year 2000. A forecast base for each individual clay end use was established and positive and negative factors were applied to obtain a forecast range. High and low range aggregations were made to obtain an unadjusted total forecast range. These results are presented in table 30.

Table 30. - Projected clay demand

Type of clay	Demand 1968	National forecast demand--year 2000 (thousands of short tons)	
		Low	High
Kaolin	3,661	16,710	23,680
Ball clay	584	2,000	3,340
Fire clay	7,802	12,250	17,340
Bentonite	1,938	4,810	9,010
Fuller's earth	856	3,350	6,130
Miscellaneous	40,969	97,200	144,000

Clay production in the study area should continue to increase. Major bentonite end uses for drilling mud and as a binder for iron ore pellets are expected to grow. The Bureau of Mines has projected the demand for drilling mud at a high of 2 million tons and a low of 1 million tons for the year 2000.

A forecast growth for the iron and steel industry of 1.75 percent per year was used to determine the forecast demand base for bentonite in the year 2000. While bentonite is the lowest-priced binder available at present, the taconite industry is interested in finding a lower cost substitute. A successful substitute would depress the bentonite industry to some extent in the study area.

The demand for common or miscellaneous clay is expected to increase as development occurs within the region.

Expanded clay and shale are construction products and are related to new construction activity which would increase if the region's coal resources are developed. In addition to current uses in residential and commercial building construction, possibilities exist for uses in highway construction. Parts of the study area are deficient in aggregate for highway construction; and expanded aggregate, while being a less costly substitute for high-transportation cost imported aggregate, offers a greater skid-resistancy than conventional materials.

Sand and Gravel

Sand and gravel are the products of rock disintegration through mechanical or chemical means or a combination of both. Both "sand" and "gravel" are terms that describe particle size regardless of chemical composition. "Sand" is here defined as any rock material within a size range of 0.0625 to 2 millimeters, while "gravel" is defined as any rock material between 4 and 64 millimeters. Material in the 2 to 4 millimeter size range is defined as "granules."

Deposits of sand and gravel are scattered throughout the Northern Great Plains area. Deposits in Montana and North Dakota are both fluvial and glacial in origin while those in Wyoming and South Dakota are principally fluvial. In North Dakota, the Missouri River marks the approximate boundary between the glaciated and nonglaciated areas, while in Montana the dividing line is north of a line approximately halfway between the Missouri and Yellowstone Rivers. Major sand and gravel deposits are shown on map B-11.

The major use of sand and gravel in the Northern Great Plains area is for construction aggregate. The U.S. Bureau of Mines preprint from the 1971 Minerals Yearbook, Sand and Gravel, lists an unspecified amount of "engine sand" production from North Dakota and 13,000 tons of industrial sand for "other" use from Montana.

Mining equipment for producing sand and gravel can vary from small unsophisticated units such as front-end loaders working in conjunction with one or more dump trucks to large power shovels or draglines, belt conveyors, and other complex equipment.

The U.S. Bureau of Mines, in Mineral Facts and Problems, describes the processing of sand and gravel as follows, "Processing may consist of simple washing to remove clay and silt and screening to produce two or more products, or it may involve more complex heavy media separation of slate and other lightweight impurities and complex screening and crushing equipment designed to produce the optimum mix of salable sand and gravel sizes. Conveyor belts, bucket elevators, and other transfer equipment are used extensively. Ball milling is often required for production of small-size fractions of sand. Permanent installations are built when large deposits are to be operated for many years. Semi-portable units are used in many pits which have an intermediate working life. Several such units can be tied together to obtain large initial production capacity or to add capacity as needed. In areas where large deposits are not available, use is made of mobile screening plants, which can be quickly moved from one deposit to another without undue interruption or loss of production."

The finished product, depending on distance from plant to job, is either trucked directly to the construction site or shipped in rail cars to a drop point and then trucked to the construction site.

Sand and gravel production decreased almost 15 million tons between 1970 and 1972 in the four states comprising the study area. Production from the study area decreased almost 4 million tons for the same period. Data on tonnage value and production with the Northern Great Plains Resource Program Region are given below. (Table 31.)

Table 31. - Sand and gravel production and value, 1970-1972

State	1970 Production*	1970 Value**	1970 Operations	1971 Production*	1971 Value**	1971 Operations	1972 Production*	1972 Value**	1972 Operations
Mont.	6.5	4.6	37	4.6	7.1	38	2.9	5.7	34
N.Dak.	2.9	2.4	87	2.4	2.1	61	2.5	2.7	46
S.Dak.	.5	.5	21	.9	1.2	18	.6	.6	18
Wyo.	2.5	2.2	38	2.4	1.8	31	2.3	1.4	33
Total	11.9	9.7	183	10.3	12.2	148	8.3	10.4	131

* Production in millions of tons.
** Value in millions of dollars.

The trend of decreasing production parallels a general decrease in sand and gravel production nationwide during this period, reflecting general economic conditions.

The Bureau of Mines, in a 1970 Information Circular, analyzed the future demand of construction materials including sand and gravel in the Atlanta, Ga., area using least square regression analysis. The findings were: "Sand and gravel demand is similar to crushed stone demand, in that the production figures are more nearly related to population and value of private construction and to a less degree to the number of residential building permits."

Development of the area's coal reserves and the resulting increase in population, industrial, commercial, and residential construction will result in an increased demand for sand and gravel.

Baked Shale

Baked shale, sometimes called clinker, natural slag, red dog, and, erroneously, scoria, is formed by the baking of shale overlying burning coal seams. The coals were probably ignited by spontaneous combustion, lightning, or some other natural phenomena during prehistoric times. The beds locally contain concentrations of cordierite ($Mg_2Al_3(AlSi_5O_{18})$) and magnetite (Fe_3O_4) produced by locally intense metamorphism. The shale beds range in color between red, yellow, black, brown, and purple, and are quite distinctive in areas in which they occur.

Baked shale is used for railroad ballast, road metal, and locally as building material. In earlier years, only small quantities of the material were used, but more recently several thousand tons of the rock have been mined each year.

The rock is quarried by conventional methods and crushed, primarily for railroad ballast and road metal.

In the Northern Great Plains Resource area, baked shale is found over wide areas of Wyoming, Montana, and North Dakota. Reserves amount to hundreds of millions of cubic yards. In Wyoming, principal burned shale resources are located in Sheridan, Campbell, Converse, and Johnson Counties. In Montana, Powder River, Rosebud, Custer, Fallon, and Wibaux Counties contain vast quantities, and, in North Dakota, the material occurs in Golden Valley, Billings, Slope, Bowman, and Adams Counties.

Development of the Northern Great Plains Resource area should largely increase the demand for baked shale, particularly for road metal, but due to the almost inexhaustible supply, increased production will have little effect on total resources.

Dimension Stone

Dimension stone (stone cut to shape) has been produced for local use in several locations within the Northern Great Plains Resource area. However, there are no available records indicating source or quantity of production.

Development of the area probably will, to a small degree, increase the demand for such stone.

Feldspar

The feldspar group of minerals is made up of several feldspar types, but commercial deposits are usually confined to orthoclase and microcline, both of which have the chemical formula $KAlSi_3O_8$. Principal uses of the material are in the ceramic industry for the production of glass, enamel, pottery, and so forth. Feldspar is also used in soaps, abrasives, and for manufacture of false teeth.

Commercial feldspars are generally found in pegmatite deposits associated with quartz, mica, and occasionally lithium minerals. Mining is usually by open pit methods, but some underground mining does occur. Processing generally consists of fine crushing.

In the Northern Great Plains Resource area, feldspar occurs in both Natrona and Converse Counties, Wyo., but production has come only from Natrona County. Total production between 1966 and 1970 amounted to only 1,281 tons. International Minerals and Chemical Corp. produced some of this quantity by surface mining methods for use in the manufacture of dental products outside the state.

Development of the Northern Great Plains Resource area would have little effect on feldspar production except in the unlikely event a large ceramic or soap industry was developed in the region.

Gypsum

Gypsum and anhydrite have the same chemical formula, $CaSO_4$, but gypsum contains water while anhydrite does not. Little anhydrite is used in this country, but during 1971 the United States consumed about 16.5 million tons of gypsum. Gypsum is used for a variety of products such as wallboard, plaster, and other building materials, and orthopedic and dental plasters. Partially calcined gypsum is called plaster of paris and is used in many types of moulding and casting. Calcined gypsum is also used as a cement retarder and as a soil conditioner, and has great potential for the production of sulfur and sulfuric acid.

Gypsum has been mined and used for centuries. The Egyptians used it in building the pyramids and before that ancient peoples used it for carving ornamental objects. One form of crystalline gypsum (selenite) was used for windows.

Mining is generally by open pit methods. Gypsum is used both raw and calcined, so processing consists of crushing and, when necessary, calcining to drive off part of the water.

In the Northern Great Plains Resource area, gypsum is currently being mined only in Meade County, S. Dak. The South Dakota Cement Commission uses surface mining methods and employs less than five miners to produce the gypsum, which in 1971 amounted to 21,000 short tons valued at about $83,000. All production is used for cement manufacture at the company's plant in Pennington County, immediately south of the study area. The gypsum is moved from mine to plant by truck.

Previously, gypsum was mined in Big Horn County, Mont. Large reserves are known in Wyoming, South Dakota, and Montana. The following table lists the counties by state in which gypsum is known to occur.

Table 32

Gypsum occurrences in Northern Great Plains Resource area[1]

Montana	Wyoming	South Dakota[1]
Big Horn	Natrona	Mead[2]
	Converse	
	Crook	
	Weston	
	Sheridan	
	Johnson	

[1] Large areas of South Dakota are described as underlain by anhydrite.

[2] Present production.

Development of the Northern Great Plains Resource area will increase demand for gypsum both in producing cement and other construction material such as wallboard.

Iron Resources

Low-grade iron-manganese deposits in South Dakota occur as terrace gravels in six of the seven counties lying within the study area. The iron-manganese minerals occur as concretions and nodules which have weathered from the Cretaceous Hell Creek formation and are concentrated along the Grand, Moreau, and Cheyenne Rivers.

According to C. M. Harrer, "Pioneer beneficiation tests made on gravels along the Grand River, Corson County, by the State's Industrial Development Expansion Agency, reportedly resulted in concentrations containing 45 percent iron, 1 percent manganese, and 15 percent silica." No resource estimates have been made for these deposits, although the quantity has been inferred as "very large."

Industrial development of the Northern Great Plains Region will have no effect on this resource. Development of these iron-manganese deposits will not occur until higher grade deposits in the United States and other areas of the world are exhausted.

Jade

Two minerals, both called jade, have been exploited by man from ancient times to the present. One, nephrite, is a calcium-magnesium silicate of the amphibole group of minerals, and the other, jadite, is a sodium-aluminum silicate of the pyroxene group. Both are high-temperature minerals of metamorphic origin, but only nephrite is known to occur in the Northern Great Plains Resource area.

Although most often thought of as green, jade can be almost any color. Much of the material of the Northern Great Plains Resource area is black or dark green, but light green does occur.

The nephrite of the Northern Great Plains Resource area occurs both as float and in place in central Wyoming, primarily Natrona County.

Development of the resources of the Northern Great Plains can only magnify the demand for nephrite jade in the area by rockhounds, hobbyists, gift shops, serious artists, and for export.

Molybdenum

Molybdenum is silvery-white metal having a specific gravity of 10.2 and melting point of 2620°, ± 10° C. Only five elements have a higher melting point. The major use of the metal is as an alloy in steel to which it imparts hardness, toughness, and strength. About 65 percent of the nearly 41 million pounds of molybdenum consumed in the United States in 1971 was for an alloy in steel. Other uses include the production of special alloys, lubricants, and chemicals.

Molybdenum was discovered in 1778 but was not used commercially until 1898. It was first produced commercially in the United States in 1917 with the opening of the primary deposit in Climax, Colo.

Molybdenum is produced from both primary deposits and as a byproduct of other deposits, principally copper. Mining is both by underground and open pit methods. Processing is rather complex. The material is first crushed, then concentrated, and finally smelted and refined.

Within the Northern Great Plains Resource area, molybdenum is contained in the uraniferous lignites and coaly rocks in Harding County, S. Dak. Although the molybdenum content is too low to allow production for that metal alone, the area may be mined for uranium and coal, thereby allowing the molybdenum to be recovered as a byproduct.

Development of the Northern Great Plains Resource area may give some impetus to recovery of the uranium and molybdenum contained in the lignite. This may come about if the lignites of Harding County are mined for power generation, coal gasification, liquefaction, or if the demand for uranium allows the economic exploitation of the uraniferous lignites and provisions are made to recover the molybdenum.

Pumicite

Pumicite, sometimes known as pumice, volcanic ash, volcanic glass, and pozzolan, is a product of volcanic action and is so extremely vesiculated that it resembles froth. Pumicite, to distinguish it from pumice, occurs as finely divided particles, whereas pumice is usually thought of as occurring in blocks or fragments of blocks. The major uses of pumicite are for lightweight aggregate, as a carrier for insecticides, as insulation, in filtration, for brick manufacture, as an absorbent, as a soil conditioner, for roads for surfacing and ice control, and as an abrasive.

Pumicite and pumice are usually mined by open pit methods and processing generally consists of crushing, screening, and drying.

Pumicite has a fairly widespread occurrence in the Northern Great Plains Resource area, but it has not been extensively exploited. Known areas of past production are in Rosebud, Big Horn, and Powder River Counties in Montana. Other areas in Montana are known to contain the material but there has been no recorded production. Natrona County, Wyo., also contains pumicite.

Development of the Northern Great Plains Resource area will increase the demand for pumicite, particularly as a lightweight aggregate.

Salt

Common salt (NaCl) is a soft, white, naturally occurring mineral called halite. The mineral occurs in evaporite deposits and is found over large areas of the United States, most notably the Gulf Coast Region, but huge deposits are located in the Permian Basin in New Mexico, Texas, and Oklahoma. Other large deposits occur in Kansas, New York, Colorado, Michigan, Ohio, and Utah. California, Nevada, and Arizona also have significant deposits. U.S. salt reserves are astronomical.

Salt has many uses in a highly industrialized nation such as the United States. In 1971, this country consumed over 44 million short tons of salt, of which 44 percent went for the manufacture of chlorine. Other uses by the chemical industry claimed another 17 percent for a total of 61 percent. Road de-icing used 18 percent of output, and food and food-related uses took about 6.6 percent. Hundreds of other uses claimed the remainder.

Salt has been mined and used since earliest man. Today, three methods are used--underground mining of rock salt, solution mining, and solar evaporation of sea water or naturally occurring brines.

Processing usually consists of crushing rock salt for snow and ice removal or, in case of brines, fractional distillation to remove impurities where a pure product is required.

In the Northern Great Plains Resource area, salt occurs in the Williston Basin area of eastern Montana, central and western North Dakota, and northwestern South Dakota. In this area, 11 salt beds have been described ranging in age from Devonian to Jurassic and in thickness up to 450 feet. It is estimated that in North Dakota alone the volume of salt is about 1,700 cubic miles. Potash (KCl) occurs with the salt in the Devonian Prairie formation.

Other salt occurrences are reported in Wyoming in Weston and Natrona Counties. Some salt is found in the sodium sulfate deposits described in another section of this report.

The only salt production from within the Northern Great Plains Resource area is near Williston, Williams County, N. Dak. The salt occurs at a depth of about 8,000 feet and is mined by solution methods by the Dakota Salt and Chemical Co. The major market for the salt is livestock feed dealers and mixers in North Dakota and surrounding states.

Development of the Northern Great Plains Resource area could have some impact on salt production in the region. Installation of coal gasification plants may require the development of gas storage cavities in the salt deposits. The economics of developing such cavities could be enhanced by the recovery of potash as well as salt. If it should become necessary to develop cavities, the resulting production of salt could stimulate a small chemical industry to produce chlorine and/or sodium. Other proposed developments, such as water diversion schemes being studied by the U.S. Bureau of Reclamation, could provide some incentive to increase the livestock industry in the area, thereby creating a significant increase in the demand for salt as a feed supplement. Increased population may also create an increased demand for salt for table use, water softeners, and possibly for snow and ice removal. The table below lists the counties by state in which salt is known to occur.

Table 33. - Occurrences of salt by county

Montana	North Dakota		South Dakota	Wyoming
Carter	Bottineau	Mercer	Harding	Natrona
Roosevelt	Divide	Oliver	Butte	Weston
Fallon	Williams*	Stark		
Wibaux	Montrail	Slope		
Richland	Ward	Hettinger		
Sheridan	Burke	Billings		
Daniels	Renville	Grant		
	McKenzie	Morton		
	Dunn	Bowman		

*Production.

Sodium Sulfate and Other Salts

Sodium sulfate, sometimes called glaubers salt, is a white salt that occurs in nature chiefly as the mineral thenardite (Na_2SO_4), but mirabilite ($Na_2SO_4 10H_2O$) and glauberite ($Na_2SO_4.CaSO_4$) are common. Sodium sulfate occurs primarily in arid regions in which evaporation about equals influent into undrained basins. It is also found in some brines. Some sodium carbonates, most notably epsomite ($MgSO_4.7H_2$) and natron or sal soda ($Na_2CO_3.10H_2O$), are commonly found with it.

The largest use of sodium sulfate is in the production of kraft paper which consumes over half of U.S. sodium sulfate production. The glass industry consumes another 20 percent. Other major users are the detergent and chemical industries. There are many minor uses for sodium sulfate such as for dyeing, mineral stock feed, pharmaceuticals, and many others.

Mining of sodium sulfate consists of scooping the sodium crystals from the bottom of dry lake beds or taking the brine before the crystals have formed. Processing the material has become rather complex. In the past, it was simply washed and calcined but today rather elaborate plants remove and recover such impurities as epsom salt which then becomes a saleable byproduct.

Before the second World War, most sodium sulfate used in the United States came from Europe, mainly Germany. Since then, however, the United States has produced most of its needs from deposits in the western part of the Nation, most notably Searles Lake in California, but some has been produced from deposits in Wyoming and North Dakota.

During 1971, sodium sulfate production in the United States was 688,000 tons, valued at about $11 million.

In the Northern Great Plains Resource area, sodium sulfate deposits are located in Wyoming, Montana, and North Dakota, and may be present in South Dakota. The following table shows the counties in the Northern Great Plains area in which sodium sulfate occurs.

Table 34. - Sodium sulfate deposits

Wyoming	Montana	North Dakota
Natrona*	Sheridan	Montrail
Johnson		Williams
Converse		Divide
		Ward

*Area of past production.

Development of the Northern Great Plains Resource area would have little effect on the production of sodium sulfate and other salts.

Stone

Limestone and dolomite occur at scattered localities throughout the Northern Great Plains Resource area. This stone may be suitable for construction aggregate after crushing, although data on the physical quality of the stone are lacking.

Locations for potential mining and crushing operations are listed below.

Table 35. - Locations for potential limestone and dolomite production

State	County	Location
Montana	Big Horn	Southwest corner
	Golden Valley	Northwest corner
North Dakota	Hettinger	North-central
Wyoming	Johnson	Western border
	Natrona	Northwest corner
	Sheridan	Western border

Reserves of stone suitable for construction aggregate are known to exist in the Black Hills area of South Dakota. Stone from this area could be shipped by rail to construction sites in Wyoming, southern Montana, and North Dakota, if suitable local sources could not be found.

Vanadium

Vanadium is a grayish, malleable, ductile metal with a specific gravity of 6.1, and a melting point of 1,900° C. It is used primarily as an alloy in specialty steels such as armor plate, cutlery, tools, and so forth. About 89 percent of the 4,800 tons of vanadium consumed in the United States in 1971 was for steel and titanium base alloys. The chemical industry claimed about 2 percent, and the remaining 9 percent was used in the manufacture of welding rods, permanent magnets, and electronic components.

Vanadium was recognized as an element in 1831, and was first used commercially about 1860 for making ink and coloring material for glass, leather, fabrics, and so forth. Its use as an alloying element in steel manufacture began about 1905.

Vanadium often occurs with uranium, and, in the United States, recovery of vanadium has been largely dependent on uranium mining. The mining method is usually conventional underground or surface mining of uranium deposits, primarily on the Colorado plateau. However, solution mining of uranium deposits has been demonstrated and may provide a significant method of recovery from certain types of deposits in the future.

In the Northern Great Plains Resource area, small amounts of vanadium have been recovered from uranium ores in Crook and Converse Counties, Wyo. These two counties along with Big Horn County probably contain the only known vanadium resources in the region.

Development of the Northern Great Plains Resource area would have little effect on future production of vanadium. Also, the vanadium resources will be recovered only when and if the associated uranium is mined.

Coal Byproduct ash

Ash, both bottom ash and fly ash, results from burning coal. Of the two, fly ash presents the greater problem for various reasons--but chief among them are the greater volume, disposal problems, and air pollution potential. Although bottom ash presents a serious disposal problem, it is not so great as fly ash due to greater volume of that material.

Reportedly, fly ash consists mainly of spherical glass particles up to about 50 microns in size and variable amounts of irregular crystalline grains and unburned coal and soot. The crystalline portion is mostly quartz, lime, magnesium, and iron oxide. It occasionally contains trace quantities of silver, copper, zinc, uranium, and other metals which sometimes approach commercial values.

During 1969, the United States produced about 30 million tons of ash from the utilization of 300 million tons of coal by the electric utility industry. Ash production is expected to increase to about 40 million tons by 1980. Evidence indicates that fly ash makes up 60 to 80 percent of the total. Within the Northern Great Plains

Resource area, about 9 million tons of subbituminous coal and lignite was used for power generation during 1971. Assuming a 10-percent ash residue (ash plus unburned coal), about 900,000 tons of ash was produced; assuming about 70 percent was fly ash, about 630,000 tons of fly ash was produced. It has been estimated that consumption of coal for power generation within the region will increase to about 120 million tons by the year 2000, resulting in about 1.2 million tons of ash. Of this, about 840,000 tons would be fly ash.

Although it is true that fly ash poses a greater problem than bottom ash for the reasons mentioned above, it is also true that it holds the greater potential for utilization. Ash has been used since Roman times for making cement. Today, fly ash is used in making cement, as construction fill, as road base, and for soil stabilization. Other uses include the manufacture of bricks, as lightweight aggregate, and as a mineral filler in asphalt. Minor uses for fly ash have been demonstrated in oil well grouting, foundry core sand, as a filler in plastics and chemicals, for blasting grit, and ice control. Even though several uses for fly ash exist, utilization is not keeping pace with increased production. For example, in 1968 the Nation produced 29.6 million tons of ash and used 5.2 million tons; while in 1969, 33.4 million tons was produced and 5.3 million tons was used--giving a percentage of usage for the two years of 17.5 and 16.2, respectively.

As mentioned above, development of the study area will greatly increase the production of ash, particularly fly ash. Utilization also will increase, but unless more uses are found for the material and greater percentages are used for known applications, utilization will not keep pace with production. The disposal problem could become great. Currently, nearly all ash is disposed at the mines as fill. This method of disposal is costly and does not allow recovery of any mineral values that may be contained in them and precludes its future use for any other purpose, without costly excavation.

Research will occur, and should be encouraged, to develop means of economically extracting mineral values such as silver, copper, zinc, uranium, etc., from ash. Also, some incentives may need to be instituted to encourage producer to make the material available for other uses.

Potential Areas of Mineral Conflicts

Development of the region's surface minable coal deposits may disrupt or preclude recovery of other mineral commodities in some parts of the region. Data are not sufficient to quantify the resource-reserve tonnages that could be affected.

Existing petroleum and natural gas fields in Campbell County, Wyo., Stark and Williams Counties, N. Dak., and Harding County, S. Dak., will preclude surface mining until the wells in the near-surface coal areas have stopped producing.

Potential uranium-bearing areas in southern Campbell and northern Converse Counties, Wyo., Billings and Stark Counties, N. Dak., and Harding County, S. Dak., could be affected if the surface minable coal deposits in these counties are developed. One clay deposit in Stark County, N. Dak., lies within an area of surface minable coal.

Mineral conflict areas are shown on plate B-12.

It is possible that the mineral commodities in conflict with the near-surface coal deposits could be recovered in conjunction with coal development. However, sufficient data on mineral occurrence, grade, and reserves do not exist to determine the probability of joint recovery.

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CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The reservation of coal rights in the Northern Great Plains Region for the Federal Government, and for all the people in the Nation, was a far-sighted move. It was based soundly on knowledge that coal is the most abundant, readily available source of fossil fuel in the United

States, whereas the amount and availability of petroleum and natural gas are of a more transient nature. This relation has been proved to be correct in a short span of only 50 years. During this period, many people were lulled into a false sense of security by the unprecedented increase in production and use of petroleum and natural gas when, in fact, they should have been concerned by the increase, and they should have planned for alternate sources of energy.

A few persons did express concern. They pointed to the undeniable facts: (1) that resources of petroleum and natural gas, which are much less abundant than coal, are being used at a much faster rate than coal; (2) the price of natural gas was too low in relation to the price of more abundant fuels; (3) much petroleum and natural gas are being used for inferior purposes, such as for generation of electric power, for which coal and atomic energy are well suited; and (4) that the disparate rate of use was inevitably speeding a day of reckoning.

In the administration of the Mineral Leasing Act of 1920, the objective has been to stimulate orderly production of coal in the Northern Great Plains Region as a benefit to local industry and to the Nation. It was never intended that the coal be preserved beyond the point of need. The day of need has now arrived, and it is time to face this problem squarely; to study trade-offs; to agree on reasonable uniform regulations for leasing, mining, and protection of the environment; and to proceed with use of the coal as the long-term national needs for energy now require.

Following are the major conclusions reached by the Mineral Resources Work Group.

1. The Northern Great Plains Region contains sufficient resources of surface-minable coal to satisfy the demand projected under the Extensive Development forecast.

2. Surface mining, unless restricted by punitive legislation, will be the primary coal recovery method employed in the Northern Great Plains Region.

3. There is no proven underground mining technology available in the United States which can recover thick-bedded coal as found in the Northern Great Plains Region without gross waste of a natural resource.

4. Senate Bill S.425, if enacted into law, would severely restrict surface mining in the Northern Great Plains Region, making unavailable some 5,974 million tons of surface-minable coal already leased and an unknown amount not presently leased.

5. Surface subsidence, the inevitable result of underground coal mining, is a pervasive, long-term form of environmental damage which is seldom mentioned and little understood by the general public, but which must be taken into consideration when comparing the vices and virtues of surface versus underground coal mining.

6. Long lead times for securing mining equipment due to steel and energy shortages could delay development of new coal mines, particularly under the Extensive Development forecast.

Recommendations

The Mineral Resources Work Group feels that the following areas deserve further investigation to improve the data base to insure responsible and objective legislation and planning.

1. Develop data on the extent, quantity, and quality of near-surface coal deposits in North Dakota as has been done in Wyoming and Montana.

2. Initiate feasibility studies on underground mining techniques and institute a research and development program aimed at the evolution of an economically viable method of full-bed recovery of the thick-bedded coals present in the Northern Great Plains Region.

3. Perform objective, detailed comparisons of surface versus underground mining in the Northern Great Plains Region, examining such aspects as the environment and reclamation, surface and ground water, resource conservation, economics, manpower requirements and availability, health and safety, production capabilities, and lead times to full-scale production. Such examinations should allow for the development of additional basic data to expand the base from which legislative decisions are, or should be, ultimately determined.